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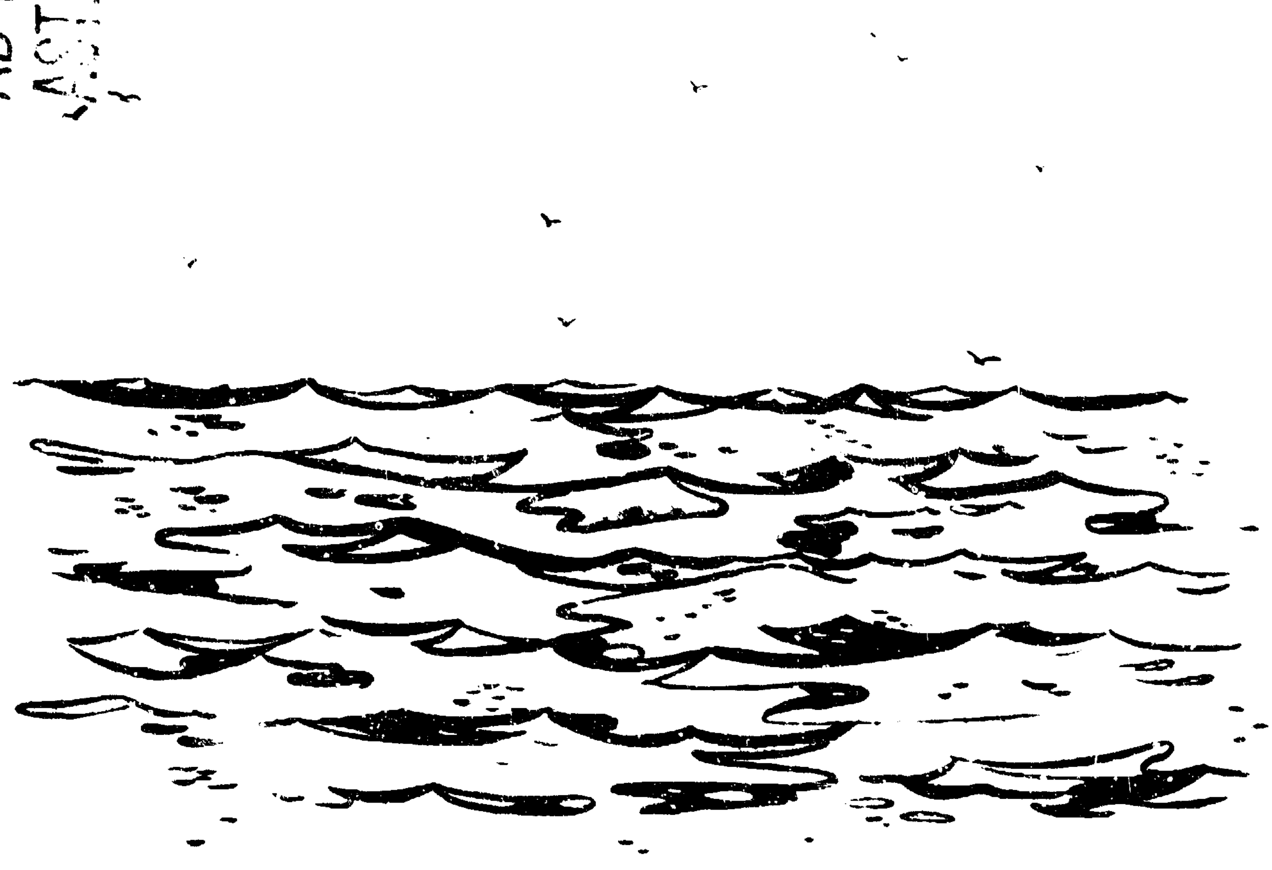
WATER-BASED AIRCRAFT



ATTACK MISSIONS

ER NO. 6602 JUN - 1955 30 APRIL 1955

55AA 24283

WATER-BASED AIRCRAFT

AN ANALYSIS OF THEIR POTENTIAL

ATTACK MISSIONS

ER NO. 6602

30 APRIL 1955

COPY NO. 26

J. D. Pierson

Technical Approval

THE GLENN L. MARTIN COMPANY

55AA 24283

FOREWORD

This is the third in a series of three reports prepared for the Office of Naval Research under Contract Nonr-1248(00). It presents a detailed analysis of attack missions.

The two preceding reports have included a summary of the results of The Glenn L. Martin Company's first year of study of the potential of water-based aircraft and an analysis of transport missions:

ER 6600 Water-Based Aircraft - An Analysis of Their Potential - Summary Report

ER 6601 Water-Based Aircraft - An Analysis of Their Potential - Transport Missions

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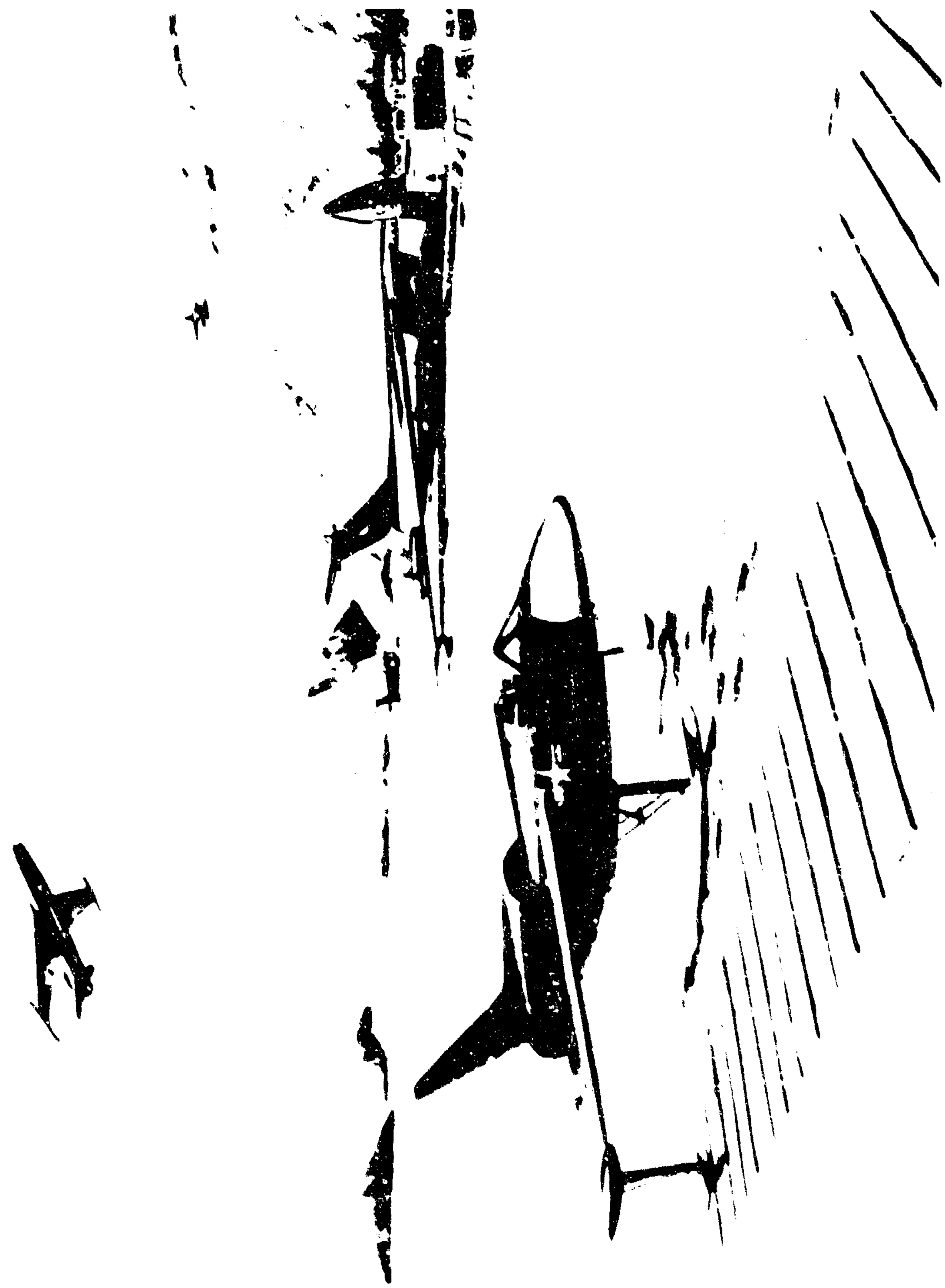

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THE GLENN L. MARTIN COMPANY
BALTIMORE, MARYLAND

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SUMMARY

In attack aircraft missions, as well as transport missions, the water basing of aircraft provides the flexibility and mobility necessary for modern warfare. This conclusion was reached in a study by The Glenn L. Martin Company for the Office of Naval Research on the potential of water-based aircraft for the 1955-1960 design period.

Water basing the attack aircraft does not impede high performance. The prime importance of successful operation at the target, against the severest enemy opposition, calls for water-based aircraft with performance in the air equal to land-based aircraft. This can be achieved by equipping the aircraft with non-buoyant hydroskis.

A typical land-based attack aircraft can be water-based, without any change in aerodynamic performance or weight, by using retractable skis. Though the weight is the same, the space required to stow the retracted skis is less than that required for retracted wheels. This additional space can be used to advantage by enlarging the bomb bay. However, the advantage of the larger bomb bay has not been considered here; it is beyond the scope of this study.

An examination of the techniques required for the operation of non-buoyant hydroski aircraft includes ground handling, servicing, ground-run acceleration, and water run for take-off and landing. Current experience on smaller aircraft indicates that satisfactory hydroski operation is feasible. Development work should be continued.

Compared to wheeled aircraft operation, the ski-equipped attack aircraft system:

1) Requires less preparation of the base area;

2) Can use a wider variety of landing surfaces and servicing facilities; and

3) Has improved blind landing qualities.

An investigation of the targets and the range requirements of the attack aircraft showed the necessity for maximum base mobility and protection against enemy attack. An analysis of dispersion problems and the relative vulnerabilities to attack gave a decided advantage to the water-based system. Requirements for base mobility with minimum

logistic support in terms of material, cost, and time (so vital to the modern concepts of mobile warfare) were best fulfilled by the water-based aircraft. This was determined from several types of basing systems, ranging from semi-permanent to small airheads. It was found that:

1) The establishment of a water base requires one-half to one-fourth of the logistic tonnage and a much shorter time than the establishment of a land base; and

2) The costs in manpower and dollars are correspondingly lower for the water base, especially where frequent moves and small air groups are involved.

The great mobility of the water-based attack system, coupled with the wide availability of suitable water bodies, gives it greater flexibility than the land-based attack system.

I. INTRODUCTION

Recent great advances in the design of water-based aircraft have brought a reawakened interest in the possibilities of performing military operations from the widely available water bodies of the world, rather than from fixed and vulnerable land bases.

In order to obtain a valid appraisal of the potential of water-based aircraft, The Glenn L. Martin Company, under contract to the Office of Naval Research, has been conducting a comparative evaluation of water-based and land-based aircraft performing military missions. The results of the first year's study are summarized in Ref. 1.

In this study, it was determined that four basic types would provide an over-all picture of military aircraft. These types are Transport, Minelayer-Bomber, Attack, and Interceptor. For Attack and Transport, the studies were carried out in sufficient detail to warrant separate reports. This report is an analysis of the attack aircraft. The transport aircraft is presented in detail in Ref. 2.

Attack aircraft have medium payload and range, versatility, and are designed to face relatively strong enemy opposition. This type of aircraft performs such missions as attack, fighter-bomber, intruder, tactical bomber, and photo reconnaissance. Each of these missions has slightly different requirements, which are discussed in this report to the degree necessary for determining comparative aircraft designs. The missions are then investigated for base costs and material requirements.

To give an accurate evaluation of water- and land-based attack aircraft potentials, the study was limited to the time span for designs begun in the 1955-1960 period. Thus, it is possible to project the present design trends into this period. The fields of development important to the study, which have been so projected, are hydrodynamics, aerodynamics, propulsion, and armament.

Hydrodynamic developments in hull forms and in dynamic lifting surfaces have been reviewed in Ref. 1. The developments in lifting surfaces are of great importance for attack aircraft. Through the use of non-buoyant hydroskis, these aircraft can be water-based with no aerodynamic penalty.

Neither non-buoyant nor buoyant hydroskis are designed to support the airplane in the water below minimum planing speeds.

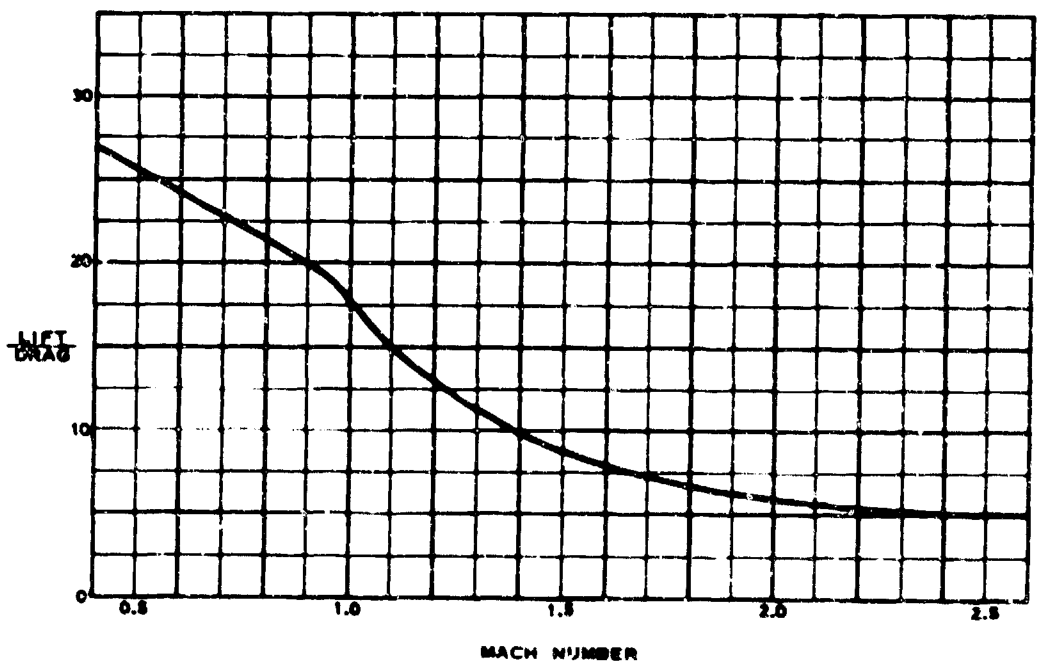

Fig. 1. Projected Lift/Drag Ratios, 1955 to 1960

A "buoyant" hydroski aircraft is one that can take off from a floating position on the water. "Non-buoyant" hydroski aircraft are not designed to take off from a floating position nor taxi on the surface at low speed. They should terminate a flight by sliding onto a solid surface. The aerodynamic penalty that results from designing a hydroski aircraft to be buoyant may be prohibitive, but the non-buoyant hydroski aircraft can be designed to float in emergencies without incurring any aerodynamic penalties. Should the aircraft have an engine failure while planing, it would drop to the surface of the water and float, although it would not, of course, even be able to rise from this position under its own power.

Aerodynamic form developments in the [illegible] of shapes and in the reduction of frontal area, typical of [illegible] high performance aircraft, have recently been spurred by the introduction of area-rule design concepts, Refs. 3, 4, and 5. The improved performance in the high subsonic and supersonic speeds is reflected in the estimated curve of lift/drag ratio versus speed, given in Fig. 1. In the era of the study, it is estimated that lift/drag ratios now associated with low speed aircraft will be obtainable at speeds up to Mach 0.[illegible] Even at supersonic speeds the drag penalty is not prohibitive.

The development of boundary layer control systems will have a substantial bearing upon the design of aircraft in the 1955-1960 period. There are three systems: Control of the circulation on the wing (or lifting surface); the reduction of drag by bleeding off the boundary layer; and gust alleviation by controlled wing circulation. Of these three types, it is anticipated that circulation control and gust alleviation will be technically feasible for aircraft in this period.

Propulsion developments have been, in a large measure, the key to the advance in speed of aircraft. Of the three major power plants in which significant developments can be expected (the turbojet, the turboprop, and the ram jet) the turbojet currently appears to have the greatest application to high subsonic and low supersonic aircraft. Since the development time on the turbojets is long, it is possible to make fairly reliable estimates of the trend in thrust available versus time through the 1955-1960 period. Figure 2 shows the projected turbojet power trend for this era.

The over-all effect of past trends on the performance of attack aircraft is shown in Fig. 3 which indicates a steady increase in both speed and gross weight with the passage of the years. However, only the speed curve has been projected along the same course for the time period under study. Developments in the field of atomic weapons plus

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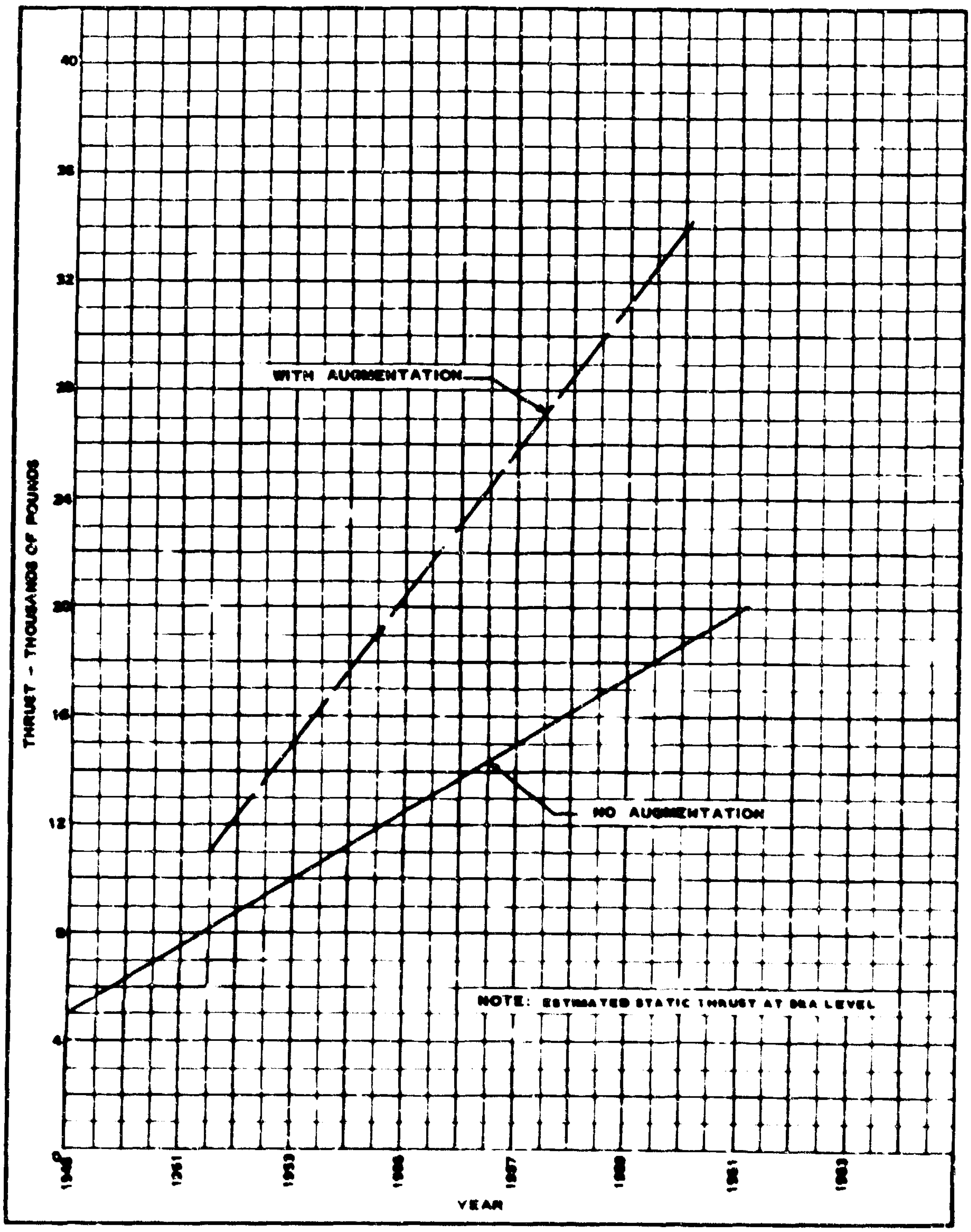

Fig. 2. Projected Turbojet Power Trends, 1955-1960

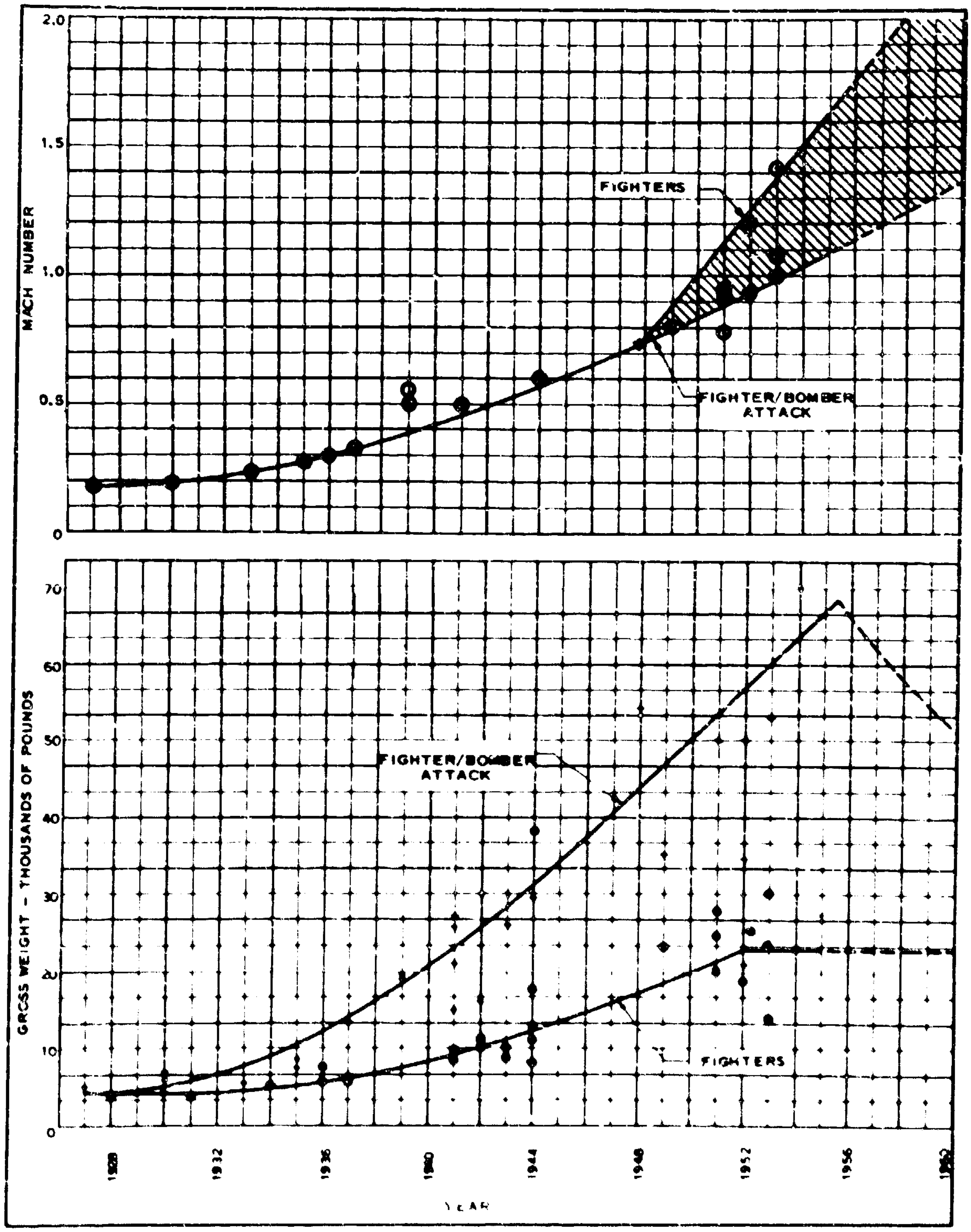

Fig. 3. Projected Speeds and Gross Weights, 1955-1960

aerodynamic improvements are expected to continue to increase the punch and speed of the attack aircraft without further increase in the aircraft weight. Thus, the trend of gross weight in Fig. 3 has not been extended along its course, but is projected on a level line for the lighter aircraft and on a downward trend for the heavier aircraft.

It is the purpose of this report to present the design requirements of attack aircraft compatible with these trends and then to show the relative merits of water- and land-based systems from military and economic viewpoints.

II. MISSION REQUIREMENTS

The major requirements for attack missions may be broadly divided into:

1) Performance in the air; and

2) Operation of the basing system.

Successful operation at the target against the severest enemy opposition is the primary consideration in the design of attack aircraft. Consequently, the aerodynamic performance of the water-based aircraft must be equal or superior to a comparable land-based aircraft. Consideration of typical targets and the limited range of attack aircraft shows the necessity for maximum base mobility and protection from enemy attack.

A. PERFORMANCE

A series of typical profiles for several of the attack missions is plotted in Fig. 4. As indicated by the trends shown in Figs. 1 and 3, supersonic speed is important at the target and, in some cases, for a large portion of the mission. High speed may be required for evasion and escape from enemy aircraft, avoidance of detection, equality in air combat, and even to escape the blast from nuclear weapons.

The moderate range of attack aircraft is a constant limitation to the mission. Attainment of a reasonable range is an important feature which cannot be sacrificed to the use of brute strength for obtaining high speed.

The importance attached to speed and range in these missions does not lend itself to quantitative evaluation. The best is none too good! Therefore, it was accepted that, to be competitive, the water-based design must be equal to the land-based design in the air.

B. TARGETS

Attack aircraft targets, illustrated in Fig. 5, include ships at sea, bridges, rail yards, trucks, troop concentrations, fuel dumps, other aircraft, and airfields. Two outstanding features may be seen: the close association of the targets to immediate

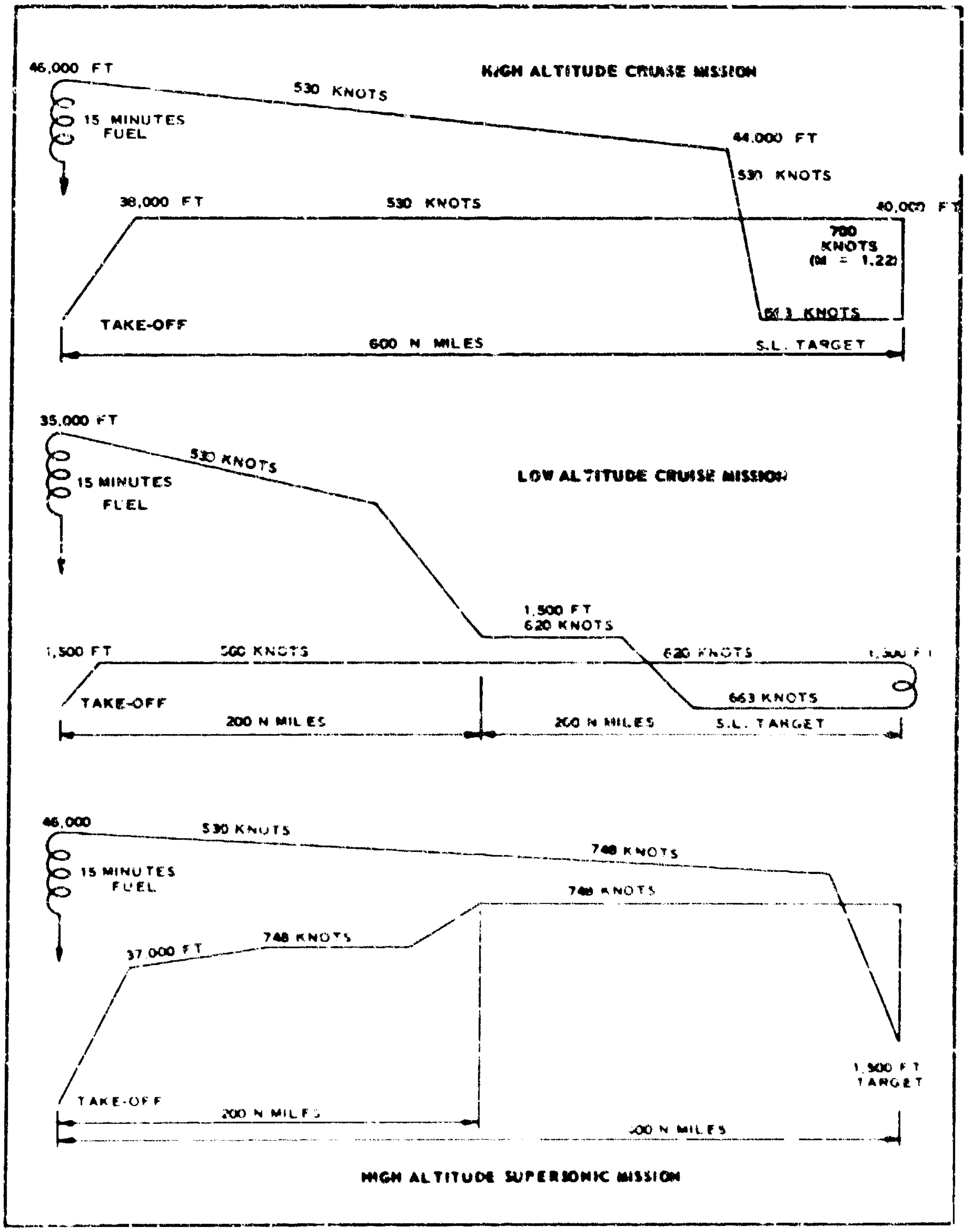

Fig. 4. Typical Attack Mission Profiles

Fig. 5. Targets for Attack Aircraft

action or fronts and the mobility of many of the targets. Unlike strategic missions where targets are selected and bombings planned in advance, the attack mission is directed at transitory situations where timing is of great importance. Thus, with only short advance notice, the aircraft must be brought to bear rapidly and effectively on the targets.

Because of the limited range and the necessity for minimum delay in striking, the attack plane must be ready anywhere around the perimeter of the enemy; as a corollary, its base is vulnerable to the enemy.

C. BASE MOBILITY

The most obvious conclusion from consideration of the mission profiles and areas of action is that the base must be mobile. This, in fact, is well recognized. The success of the aircraft carrier in performing this job during World War II and during the Korean War is a matter of history. The tactical necessity of short lag time and close contact with the enemy is demonstrated by the current perimeter defenses in Europe and other available areas surrounding the Eurasian land mass. Current specifications for several attack missions include definite requirements for the mobility of the basing system (e.g., Fighter-Bomber Specifications, Ref. 6).

The huge perimeter of the Eurasian land mass and the possibility of widely separated hot spots make a complete ring of fixed bases desirable but geographically, politically, and economically impossible. In addition, the great depth of defense inherent in the land mass of Asia would make a perimeter series of fixed bases ineffectual if the area of conflict moved very far inland.

This requirement for base mobility becomes even more important when we consider the potential of water-based transports. Their ability to penetrate deeply into enemy territory (as analyzed in Ref. 2) will require that tactical air support be able to move-in rapidly and be supported in the same area. Here, the base must be not only mobile but air transportable as well.

Five types of bases will be considered in this analysis:

Semi-permanent - bases designed to be used for several years;

Temporary - Short-lived bases transportable by truck;

Airhead and Small Airhead - short-lived bases transportable by airplane; and

Aircraft Carrier.

Each type of base maintains 90 attack aircraft with the exception of the Small Airhead base which maintains 30 attack aircraft.

D DISPERSION

The second conclusion drawn from the mission study is that these mobile bases must be successfully defended against enemy attack. The threat to a base, whether it is on land or water, must be met by minimum investment in the area, dispersion of aircraft and service areas, concealment, strong defenses, or by other means; nonetheless, it must be met. An even greater necessity for dispersion must be considered in the future because of the area damage possible with atomic weapons.

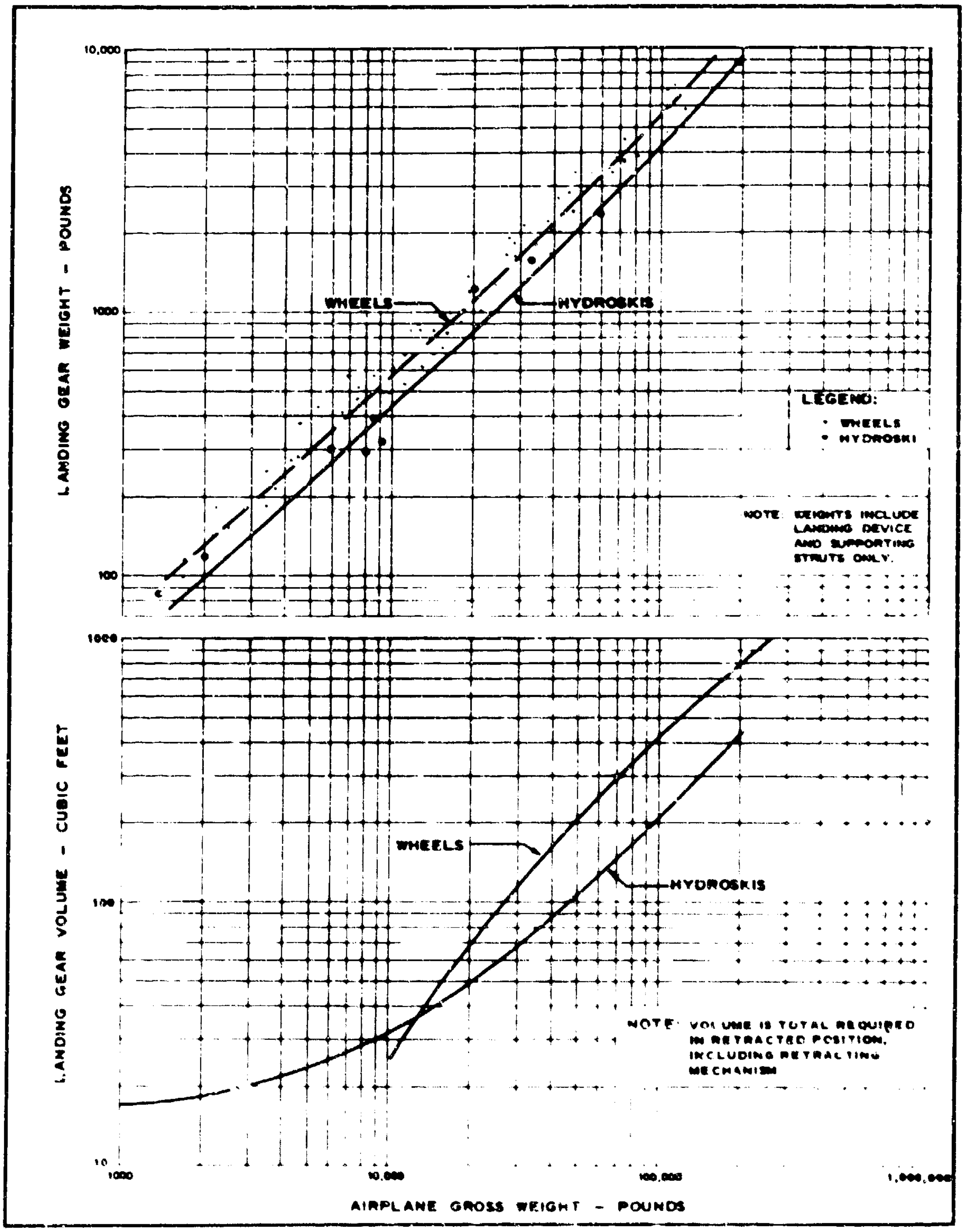

Fig. 6. Weight and Volume Comparison of Wheels and Hydroskis

III. COMPARISON OF AIRCRAFT DESIGNS

The requirement for identical flight performance of water-based and land-based aircraft is met by water-basing on non-buoyant hydroskis. With gear retracted, the water- and land-based configurations will appear almost identical.

A current proposed fighter-bomber design was selected as typical for the group of missions. This was used as a basis of comparison for structural studies. Little difference in weight was noted, but the water-based version required less volume for its ski landing gear than the land-based version required for its wheel landing gear.

A. LANDING GEAR

Statictical studies of hull, fuselage, and landing gear weights (Ref. 1) have shown that above 100,000 pounds gross, the hull form seaplane has a weight advantage over the comparable landplane fuselage and landing gear. Also, developments in hull configurations and the advent of jet power have combined to yield hull-form seaplanes of competitive aerodynamic performance. In the attack category, the lower gross weight (20,000 - 60,000 pounds) and the emphasis on high-density design make a hull-type configuration inappropriate.

High density design for attack aircraft leads directly to the use of non-buoyant hydroskis. The gross weight divided by total aircraft volume for many projected designs yields a density of 30 to 40 pounds per cubic foot. It is obviously difficult to obtain a satisfactory water based configuration with more than one-half of the body under water while in the static buoyant condition. The development of non-buoyant skis, such as those of AMC-Edo and All American Engineering (Refs. 1 and 7 through 10) has contributed to the solution of this problem. Although for safety the aircraft will float by virtue of its fuel tanks and cabin design, the ski configuration is not designed for take-off from a floating position. When not moving, the aircraft must be supported by outside means (the shore, floating ramps, or mats), but the take-off and landing runs are made on the water.

The weight and volume of hydroskis compared to wheels has been summarized in the first report of this series (Ref. 1). The results are shown in Fig. 6. These data were compiled from a number of sources. The characteristics of each ski installation, along with the weight and volume, are tabulated in Appendix A.

In order to keep a CONFIDENTIAL classification for all three reports of the series on Water-Based Aircraft (ER 6600 to ER 6602), the Standard Characteristics, which have a SECRET classification, have not been included here. They may be obtained from The Glenn L. Martin Company as a supplement to this volume.

To obtain copies of the Standard Characteristics, ask for:

"Fighter-Bomber Design Study, Aerodynamic Data and Standard Characteristics," pages xii, xiii, xvi, xvii, xviii, (Figs. 1, 2, 5, 6, and 7), Engineering Report No. 5609, The Glenn L. Martin Company, October 1953. SECRET

Fig. 7-11. Standard Characteristics of the Attack Aircraft

There is a significant reduction in the volume required for the ski installation compared to that for wheels in the attack aircraft weight range. This space could be used to increase the armament load of the aircraft. However, the quantitative evaluation of the resulting increased mission effectiveness for water basing is beyond the scope of this initial study. Thus, the two configurations are assumed to be identical in the air.

B. SELECTION OF CONFIGURATION FOR COMPARISON

Attack aircraft designs for the 1955-1960 period are currently under investigation at The Glenn L. Martin Company. One of these, a supersonic fighter-bomber with internal bomb bay, is being studied under an Air Force Contract. The gross weight is 30,000 pounds for a basic 600 nautical-mile high-altitude mission. The wing is designed to take maximum advantage of leading edge suction, and the fuselage has been indented and arranged to give the over-all configuration an exceptionally good area-rule curve. Because of the design, it was believed that this aircraft would be typical of those developed in the 1955-1960 period and therefore would be applicable for use in the aerodynamic, structural, and economic evaluation. A summary of the characteristics and capabilities of this airplane are presented as a supplement to this report (see Figs. 7-11).

The design study of the tri-ski gear is more fully discussed in Appendix B. All planing surfaces were made retractable (flush with the body and wings), thereby retaining the same external shape as the land-based version. A weight analysis and comparison revealed that the ski-based version was a few pounds lighter. Thus, since both weight and external appearance were approximately the same, no difference in aerodynamic characteristics or performance would be expected between the land- and water-based versions.

A weight comparison summary of the two versions is shown in Table 1. Structural considerations and detailed weight determinations for both types of aircraft are given in Appendix B.

The water-based configuration is shown with gear extended in Fig. 12.

TABLE 1

SUMMARY WEIGHT COMPARISON - WATER- AND LAND-BASED ATTACK AIRCRAFT

Item	Water-Based			Land-Based		
	Weight		% Gross Wt	Weight		% Gross Wt
Wing	3468 lb		12.3 %	3377 lb		11.9 %
Tail	988		3.5	988		3.5
Fuselage	3436		12.1	3648		12.8
Landing Gear	1056		3.7	1138		4.0
Surface Controls	673		2.4	673		2.4
Engine Section	273		1.0	273		1.0
Total Structure	9914		35.0	10,097		35.6
Propulsion	3854		13.6	3,854		13.5
Fixed Equipment	3305		11.7	3,305		11.6
Weight Empty		17,073	60.3		17,256	60.7
Useful Load						
Crew	230			230		
Fuel	7878			7878		
Oil	50			50		
Guns (30 mm)	990			990		
Bombs	2072			2072		
Equipment	20			20		
TOTAL		11,240	39.7		11,240	39.3
GROSS WEIGHT		28,313 lb	100.0 %		28,496 lb	100.0 %

NOTE: Although the ski-equipped configuration has space available for a larger bomb door, this change has not been included so that the added weight of the larger door will not disturb the comparison.

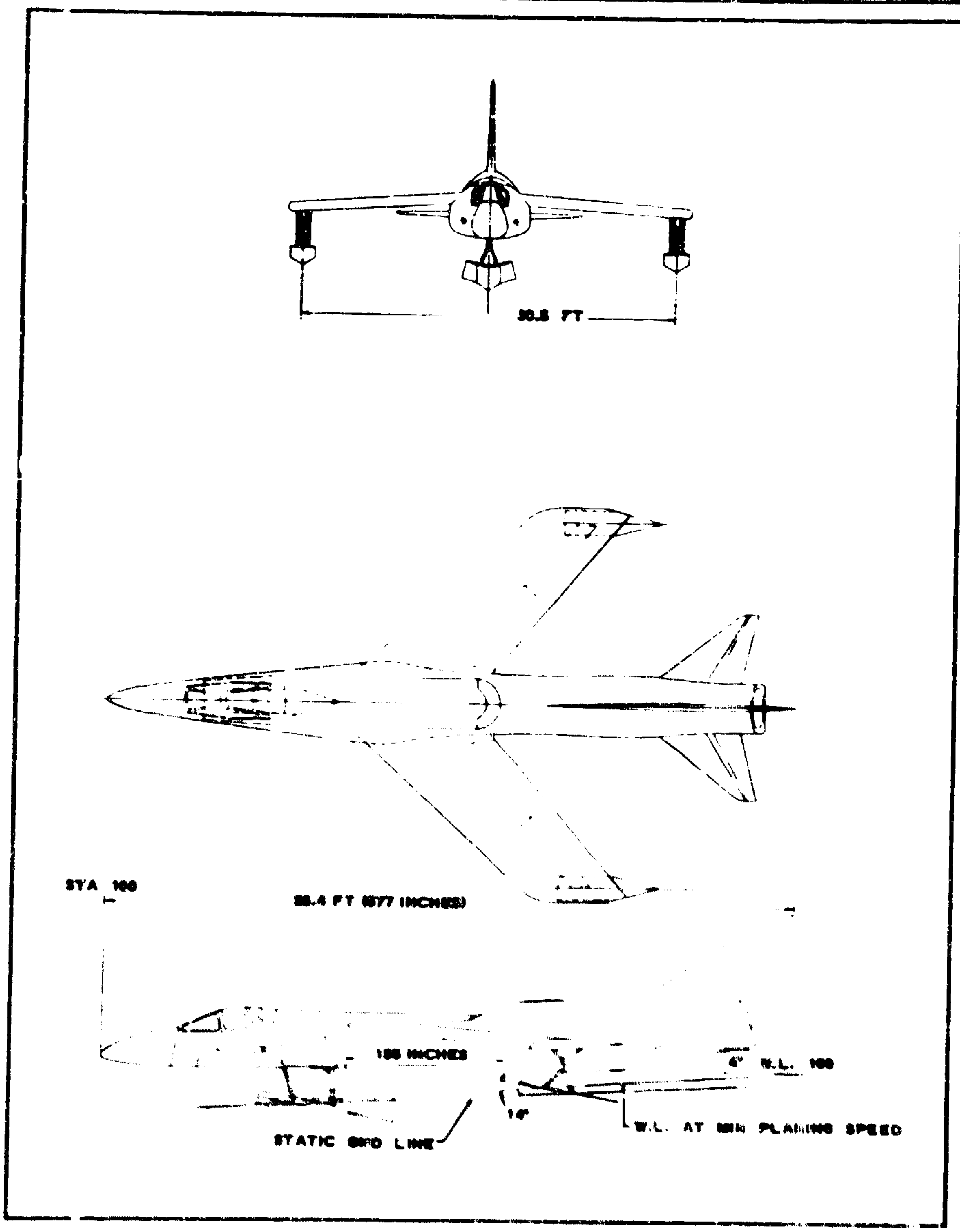

Fig. 12. Hydroski Version of the Attack Aircraft

IV. ANALYSIS OF LANDING AND TAKE-OFF OPERATIONS

The selection of the non-buoyant configuration with skis for the attack mission introduces new problems in aircraft handling on the surface. The techniques for ground handling, servicing, acceleration runs on the hardstand, taxiing, and take-off and landing are discussed in this chapter. On the basis of current experience with similar types of aircraft and their models, these techniques seem feasible (Refs. 1 and 7-10).

In this chapter, the requirements for water-, land-, and carrier-based attack aircraft are compared on the basis of facilities, ease and safety of operation, and provisions for landing and take-off. These requirements are then used in the following chapter for the evaluation of the water-based system.

A. OPERATION OF WATER-BASED ATTACK AIRCRAFT

1. Handling and Servicing

A considerable amount of ground handling is necessary in the operation of any aircraft. They have to move or be moved from one point to another for maintenance, spotting for take-off, and for parking. Ground movements must be accomplished rapidly and with ease so that maximum launch and landing rates may be realized and maintenance and servicing activities expedited. Normal ground handling should be accomplished without starting up the jet engine.

For the very small aircraft on skis, this has been accomplished by incorporating wheels for taxiing on hard surfaces. Wheel-ski combinations have been used successfully for landings on water, land, snow, and various combination conditions of water, slush, and land (see Ref. 11). In the larger aircraft, such as the attack, the incorporation of wheels for taxiing on hard ground will be a serious weight and volume penalty.

On soft or slippery surfaces, skis have proved suitable. In general, the experimental aircraft have furnished their own power for taxiing or positioning on the shore, sometimes with a little manual assistance. The Baroudeur aircraft (Ref. 12) is easily handled on a dolly where it either maneuvers under its own power or is towed by a jeep. Ordinarily the Baroudeur takes off on the dolly, but it has been successfully operated with skids on mud, dry grass, beaches, and stony ground. After overcoming initial friction, the skids offer little resistance on dry grass. Even paved roads and runways were used after greasing. Extensible claws were mounted on the skids for steering.

For ground handling on most surfaces, the normal truck and towing equipment associated with air support would be able to slide an aircraft on its skis and move it from landing position to servicing area or take-off position. However, a much smoother operation could be obtained with handling equipment designed for use with ski aircraft, like the self-propelled dolly system illustrated in Fig. 13. Bodily lifting the aircraft clear of the ground, the carrier can transport it to any desired area with a minimum of time and effort.

Operations of the water-based attack airplane from a shore area can be conducted with the same types of servicing facilities and maintenance personnel used with land-based aircraft. However, the accessibility of the water area provides the means for operation of the ski plane in unprepared areas where land transportation may be restricted or entirely lacking. In this case, personnel and supplies could be transported by boat, and fueling would be accomplished through an underwater distribution system similar to that shown in Fig. 14.

2. Ground Run

The design analysis and the take-off performance of the water-based attack aircraft with skis are given in Appendix B.

To allow a rapid acceleration to minimum planing speed, the ground run must not offer excessive resistance. For the thrust-to-weight ratio of 0.5 for this design, a friction coefficient of 0.2 or less is desirable (see Appendix B, Sections A and B). Although many natural beaches of dirt, gravel, clay, and mud offer the desired low friction, it will be assumed for this study that all weather operation requires a prepared strip for the ground portion of the take-off run. A prepared strip may also be required to minimize the effects of the jet blast.

This prepared strip may consist of pierced-steel planking, but this would probably require a low friction non-metallic ski bottom. A simpler and possibly better surface for a water-edge location is a heavy wood planking that would protect the subsurface from erosion. Wet down for take-off, this surface would provide low friction for a metal ski bottom.

The area of the strip is determined by the width of the wing tip skis (50 feet) and the acceleration run (120 feet). An area 75 x 200 feet is assumed to give an operational margin allowing 80 feet for jet blast deflection and safety margin. One end of the strip extends into the water to a depth equal to that of the extended ski when the aircraft has water-stalled.

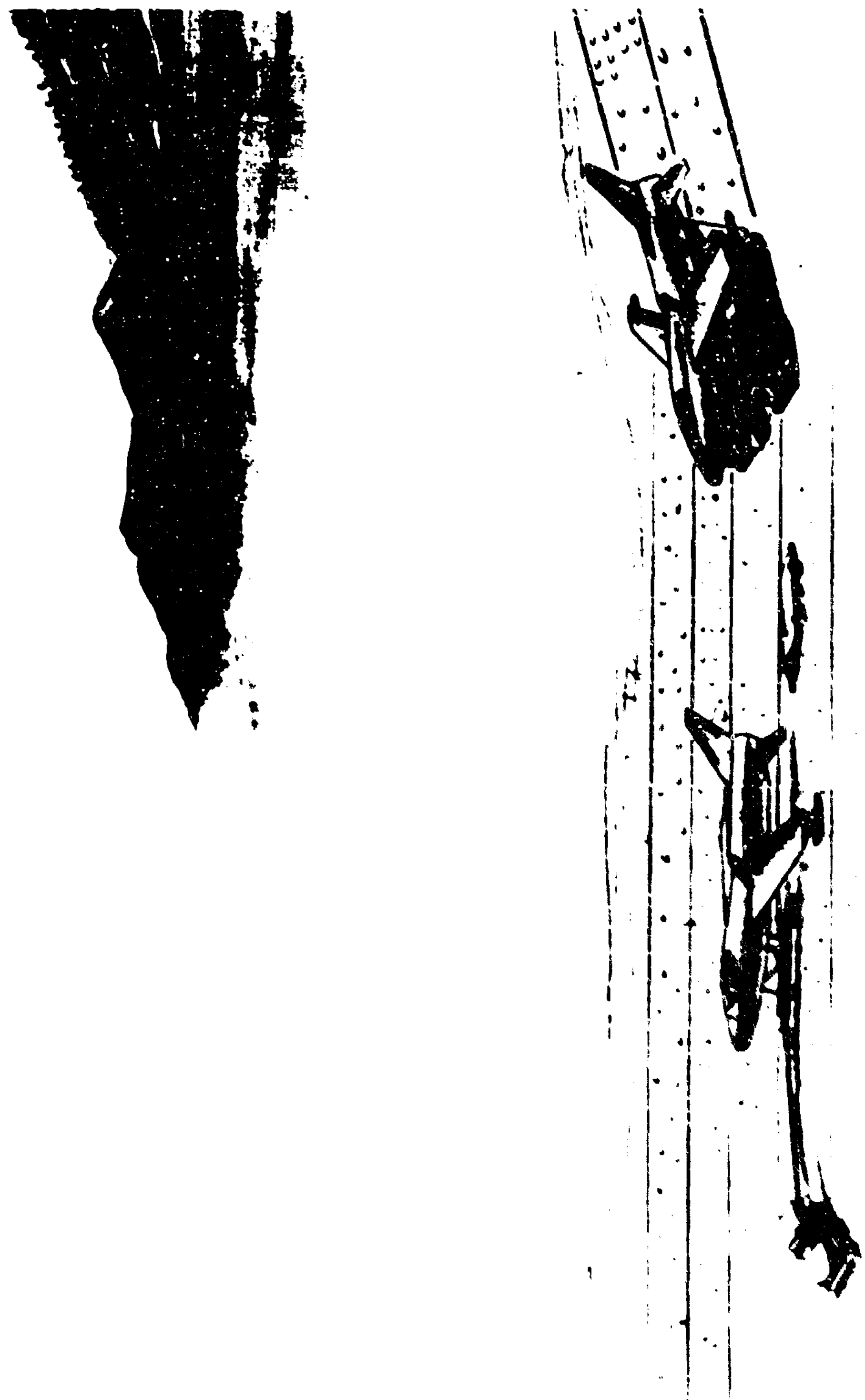

Fig. 13. Handling of Hydroski Aircraft on Shore

Fig. 14 Fueling System for Water-Based Aircraft

The transition run from the ground to the water has not been a problem on current small ski aircraft. For larger and more heavily loaded skis, the steepness of the ground run and the required trim conditions on entering the water may require the development of special techniques (such as automatic ski trim changes) for successful transition.

3. Water Run

The non-buoyant attack aircraft with hydroskis must enter the water at speeds above 30 knots and must leave the water before the speed falls below 30 knots to avoid water stall. However, the aircraft is designed to float in case of a water stall. As indicated in Appendix B (Fig. 31), the water drag is a maximum at the water stall speed and diminishes as speed increases. The normal gross weight take-off run from ramp edge to take-off speed of 140 knots requires approximately 25 seconds. The distance covered is approximately 3500 feet.

Current experience with the various ski-type aircraft shows that planing presents few problems. Stability during planing is excellent. Notably, the ability to perform turns, taxi runs, and take-offs in relatively high cross winds has been demonstrated for many of the twin-ski configurations. It is anticipated that a tri-ski configuration with the same desirable characteristics, can be developed but it may require trim angle control for the wing tip skis.

Although the landing run is no longer than the take-off run (3500 feet) it is anticipated that reverse thrust provisions will be incorporated in the engines. This will not only assist in a more controlled approach to the beach but will also provide a powerful directional control system with partial vane deflection.

The landing impact computed as in Ref. 13, for a rigidly mounted ski, is 3.5 g at full gross weight for a contact sinking speed of 10 feet per second. Based upon current experience and recent theoretical analyses, such as Ref. 14, the load factor of 3.5 g is estimated to occur with a sinking speed of 15 feet per second for the shock strut mounted configuration.

The technique for power-off landings will require an approach close to the shore line at a slight angle so that the position of touchdown is not too critical. This will also allow a longer run on the beach so that a higher grounding speed will be feasible. Although in most cases the power-off landing could be ended on the shore or in shallow water, sufficient buoyancy is incorporated in the basic design of the aircraft for emergency landings in deep water.

4. Spray

Effects of spray on a ski-equipped aircraft must be considered, particularly on the engine air intake. The configuration chosen for study appears to be very favorable from a spray standpoint due to the location of air intake and wing. The air intake is well aft on top of the fuselage. It is also protected by the wing which is located below and ahead of it. Furthermore, experience has shown that the necessity for maintaining a fairly high water speed causes most spray to be thrown to the rear, too low to affect the intake. The spray pattern would be very much like that formed by a seaplane at planing speeds where spray is thrown well aft of the aircraft wing and propellers. Problems concerning spray arising in a hull seaplane when not on the "step" or when rising onto or settling from the step, will not affect the non-buoyant ski aircraft since, in effect, it is on the step or planing all the time that it is on the water.

Ice formation on seaplanes on the water has always been a serious problem. By using an anti-icing solution on the aircraft, this has been partially remedied and seaplanes have been successfully operated in cold regions. Further intensive development should continue and the problem should be solvable by the time the hydroski aircraft is operational.

5. Open Water Operation

Operation of the water-based attack airplane from bases where beaching is not possible, introduces additional problems.

The most immediate need is a place for the aircraft to come to rest. One such system, reported in Ref. 30, consisted simply of a floating raft of sufficient length to receive the planing aircraft plus additional length sufficient for acceleration to planing speed. The system illustrated in Fig. 15 represents a further development for handling larger numbers of planes. The arresting float segment is relatively short and incorporates arresting gear to receive the aircraft from the planing condition. The take-off segment of the unit is longer and is designed to float with the ski tracks awash to provide the acceleration run with water lubrication.

It is anticipated that the arresting float segment would carry normal fuel and stores requirements as well as basic servicing gear. Thus, each float and aircraft would be a partially self-sufficient unit. A common take-off segment would be used, the number of aircraft per segment being determined by the scrambling time required.

Fig. 15. Handling of Hydroski Aircraft Off Shore

The float system illustrated in Fig. 15 could be used in open water operation in combination with supply ships and water-based transports. It would also be used in other areas where the shore terrain was unusable or where operations might be delayed by preparation of the beaches. The component sections of the raft would be air transportable by the large logistics support seaplane described in Ref. 2. In fact, the lightering rafts described for use with the transport in unprepared areas could be used for water basing the attack airplane.

Open water operation introduces problems of rough water take-off and landing. For the non-buoyant hydroski aircraft there are two design problems that must be considered: impact loads and submersion of the skis.

The ability of the skis to absorb the landing impact in 2-foot waves without shock absorbers has been amply demonstrated. In higher waves, up to 5 feet, some full-scale experience has been obtained which indicates satisfactory loads for the hydroski attack airplane. However, impact characteristics in a wide range of sea conditions or in larger waves are not yet determined for the aircraft with shock-mounted skis.

Submersion of the skis during wave impacts is not a serious problem in itself. The ski continues to lift even though submerged momentarily. However, the submergence and emergence of the ski nose gives rise to a heavy spray which may drench the engine. The limiting wave size for such a condition is about the same as for the landing load factor.

It is anticipated that the continuing program of research with both model and full-scale hydroski aircraft will provide the technical information for rough water operation. At the same time, it is recommended that the methods of local smoothing of the sea be thoroughly investigated. Preliminary investigations of the smoothing effect of a ships wake (Ref. 1[illegible]) and the use of wave suppression barriers to reduce wave height (Ref. [illegible]) have indicated improvements which will substantially increase the open water potential of the water-based attack aircraft.

B. COMPARISON OF WATER BASED WITH LAND- AND CARRIER-BASED OPERATIONS

1. Maintenance and Operational Facilities

Attack aircraft [illegible] regardless of the basing method. [illegible], the bulk of [illegible] equipment, personnel, spare parts, [illegible], [illegible], [illegible], etc. are the same for all bases. For the shore-based ski aircraft or the land-based aircraft, the installations for housing, repair shops, navigational aids, maintenance equipment, and storage will be comparable, although the desired dispersion is more easily obtained in the water base.

Both the carrier- and the open-water-based attack aircraft are a part of a similar self-contained complete mission unit. The segments of the unit for the water-based mission will be smaller and less complex than the carrier itself, even though the total services required are the same. In addition, the water-based attack can be supported by air transport in areas inaccessible to either carrier- or land-based aircraft.

2. Handling and Servicing

The handling and servicing of aircraft has been developed to a high degree of efficiency on the aircraft carrier and at well-equipped land bases. Even in areas of minimum preparation, the ease of taxiing or otherwise moving the wheeled aircraft is familiar to operating personnel. Since the inclusion of wheels with the skis of a water-based attack design was determined to be too costly in weight and volume, additional equipment (dolly, special tow truck, lift truck, or similar equipment) will be necessary in many cases to provide easy and rapid movement of the aircraft on the ground (as indicated in Section A-1 of this chapter).

This special equipment, however, will be far lighter in weight than taxiway construction requirements for the land-based aircraft. When the ski loading (less than 4 psi) is compared with normal tire pressures (40 to 100 psi for attack aircraft), the difference in surface preparation requirements for the taxiways is evident. All-weather operation of the land-based attack aircraft will require a pierced-plank, macadamized surface for taxiing or parking while the water-based aircraft will need no preparation beyond that provided for the trucks and other vehicles common to both types of basing.

3. Landing and Take-Off Surfaces

With allowance for a safe stopping margin, the attack aircraft design used for this comparison requires approximately 6,000 feet for take-off and landing. The carrier flight deck length is only a small fraction of this distance by virtue of self-generated wind, arresting gear, catapults, and exceptional pilots. On the ground, the surface must be suitably compacted and covered for the full distance with sufficient width to allow some approach error (approximately 150-foot width required, Ref. 17)

These costly prepared strips are almost entirely eliminated with the water-based concept. Only the short acceleration strip (approximately 200 feet by 75 feet wide) need be surfaced. The most restricted water area for take-off and landing (narrow canal or river) is equivalent to a one-strip airfield, while the usual water body is of sufficient size to allow simultaneous take-offs from a number of separated shore stations.

A comparison of terrain requirements is also significant to the analysis of take-off and landing surfaces. Land-based operations require a relatively flat and well drained surface for runways, taxiways, and surrounding facilities (about 2 square miles per strip). The hydroski aircraft requires a reasonably sheltered water area about 6000 by 600 feet (shallow water, marshes, snow fields, etc. are satisfactory if air transport is not needed for supplies) with a small, reasonably flat beach and shore area for support facilities.

Geographical studies reported in Refs. 1 and 2 pertain particularly to larger and deeper water bodies than those required by the hydroski plane alone. However, even on that basis, the relative availability of water bodies and suitable ground terrain favored the water basing of aircraft in the Eurasian land mass.

It should be noted that there is another advantage in the simplicity of water basing where small operations for short periods of time are necessary. In this case, it may be desirable to operate from the beach or rafts with no preparation of the area. Instantaneous availability of the base would be limited only by the amount and quality of the beach or the ability to transport rafts into the area.

4. Safety

It appears that a forced landing in a ski aircraft results in considerably less chance of personnel injury and considerably more chance of recovering the aircraft undamaged than is the case with conventional aircraft. If a pilot were faced with a forced landing, he would have a wide choice of surfaces upon which a safe landing could be made. The only important requirement would be a reasonably smooth surface, and it would not matter much what it was. It could be soft mud, water, snow, etc.

In most cases where the aircraft is water based, it would be possible to provide considerably more than the minimum water area. This would result in much greater safety during aborted take-offs or engine failures during the critical period of take-off or landing. Engine malfunctions during landings and take-offs have always been critical for land planes because of limited runway space, soft or rough terrain beyond the runway, and the usual obstructions.

Beyond the safety factors associated with malfunctions, the water base provides easier landings in limited or zero visibility. Because of the size of the usual landing area and the excellence of radar contrast between land and water, either ground- or air-controlled landings can be routine. This has been demonstrated at many sea exercises where land- and carrier-based aircraft have been grounded by heavy fog while seaplanes continued to operate.

This capability for all-weather operation of the water-based aircraft is particularly important to the attack mission. Transient targets and the vulnerability of the base to attack make prompt action imperative in any kind of weather.

5. Flexibility

Whereas the carrier aircraft for an attack mission can generally operate from land bases and land-based aircraft can operate from carriers with the addition of arresting hook (and structural beef-up), both wheeled vehicles are restricted to prepared runways.

The water-based ski configuration can also be modified to land on the carrier deck and be catapulted for take-off (see Appendix B). In addition, the skis are suitable for landings on mud, snow, sod, plowed fields, and similar surfaces - as well as on water.

Although operation of the skis on rough or abrasive surfaces will require special bearing skin or frequent replacement, the flexibility of such a system makes it ideal for attack missions.

V. EVALUATION

The various types of attack missions, the characteristics of a typical aircraft design, and the operational problems to be met have been discussed in previous chapters. Early in the study it was determined that the capability in the air must and can be equal for the land- and water-based aircraft. Therefore, the evaluation of the relative merits is primarily a comparison of the basing systems.

Several typical types of operations were used to establish the size of the air group and the required bases. For these bases the relative vulnerability and mobility were evaluated in terms of dispersion, logistics, and cost for both water- and land-based missions.

Water basing offers a means of approaching the ideal in dispersion of aircraft. Although the nearness of the water body to the parking and servicing areas introduced additional types of damage possible in underwater atomic bursts, these are relatively ineffective compared to the damage of an air burst. Thus, the value of the dispersion afforded by water basing is not reduced.

Tonnage requirements and related costs are less for the water-based attack system, particularly for the smaller air groups. These lower requirements, in turn, result in a shorter time and lower costs for moving water bases than for land bases.

The mobility of the water bases for attack missions, plus the wide availability of suitable water bodies, gives a greater flexibility to water-based systems.

A. SYSTEMS CONSIDERED

The aircraft used for the evaluation study is a supersonic, turbojet fighter-bomber of approximately 30,000 pounds gross weight. Its configuration and capabilities are included in a supplement with a SECRET classification (see Figs. 7 through 11). Problems of landing, take-off, and ground handling were discussed in the preceding chapter and the feasibility of the method of operation has been indicated.

Five types of bases have been considered in the analysis: semi-permanent, temporary, airhead, small airhead, and carrier. The number of aircraft facilities, personnel, supply systems, and other pertinent data are given in Figs. 16 and 17 for each type of base.

SEMI-PERMANENT LAND BASE:

90 attack aircraft, tools, and spare parts
1 6000 ft x 150 ft asphaltic concrete runway, each end paved with portland cement concrete for 500 ft
1 6000 ft x 40 ft asphaltic concrete taxiway
91,000 sq yd concrete apron
50 prefabricated buildings
1 temporary hangar
2300 personnel
Base supplied by land transport

TEMPORARY LAND BASE:

90 attack aircraft, tools, and spare parts
1 6000 ft x 150 ft double Marston Mat runway covered with asphalt over compacted sub base
1 6000 ft x 40 ft single Marston Mat taxiway covered with asphalt
91,000 sq yd apron of the same material
150 tents; prefabricated buildings for shops
1 temporary hangar
1500 personnel
Base supplied by land transport

AIRHEAD LAND BASE:

90 attack aircraft, tools, and spare parts
1 6000 ft x 150 ft double Marston Mat runway covered with asphalt over compacted sub base
1 6000 ft x 40 ft single Marston Mat taxiway covered with asphalt
91,000 sq yd apron of the same material
250 tents
2300 personnel
Base supplied by 90 C-123 transports

SMALL AIRHEAD LAND BASE:

30 attack aircraft, tools, and spare parts
1 6000 ft x 150 ft double Marston Mat runway covered with asphalt over compacted sub base
1 6000 ft x 40 ft single Marston Mat taxiway covered with asphalt
30,000 sq yd apron of the same material
70 tents
767 personnel
Base supplied by 40 C-123 transports

NOTE: All personnel allowances include an appropriate amount of local defense.

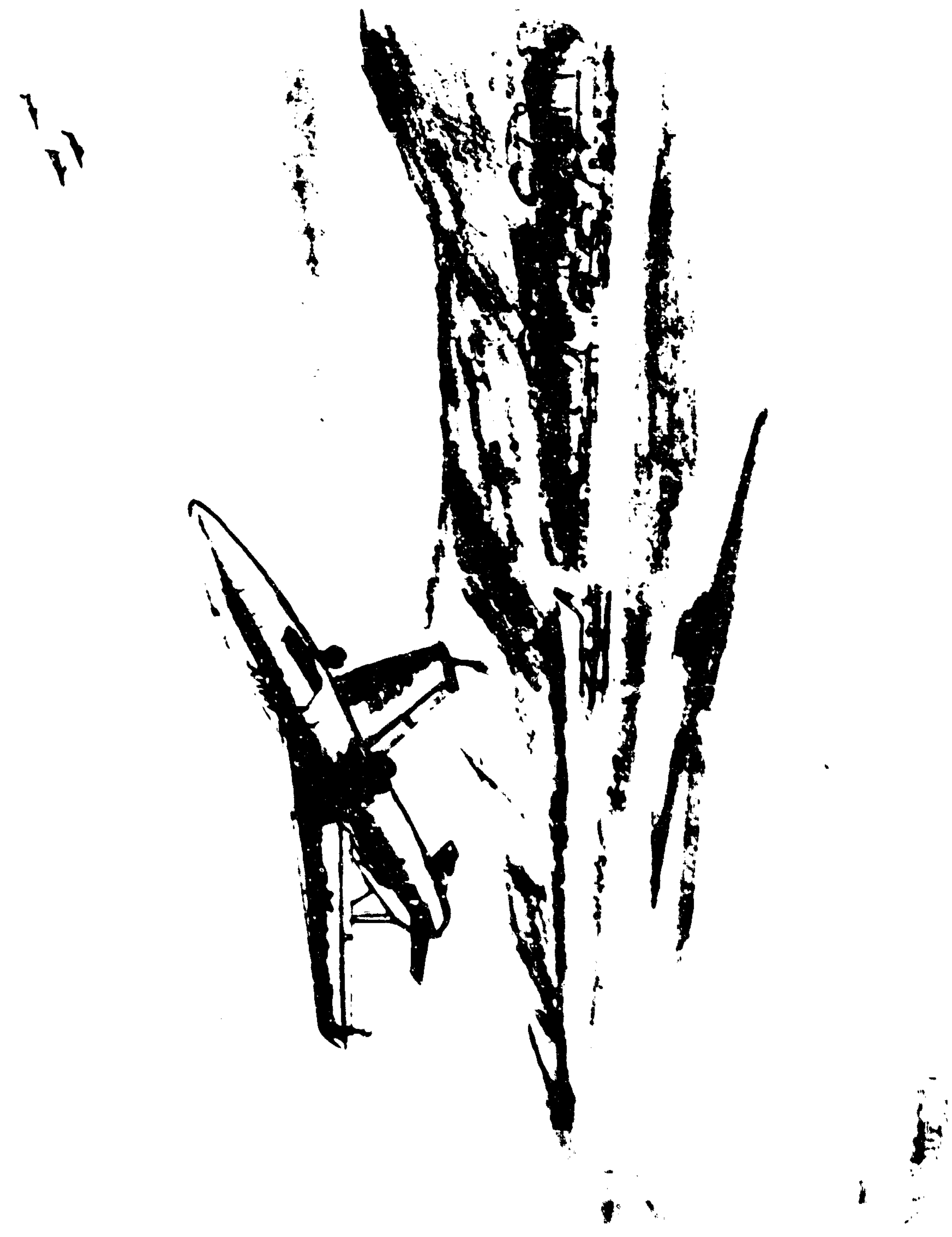

Fig. 16 Requirements for Land Bases

SEMI-PERMANENT WATER BASE:

90 attack aircraft, tools, and spare parts
1 wooden ramp 200 ft x 75 ft for take-off and landing
91,000 sq yd concrete apron
50 prefabricated buildings
1 temporary hangar
2300 personnel
Base supplied by land or water transport

TEMPORARY WATER BASE:

90 attack aircraft, tools, and spare parts
1 wooden ramp 200 ft x 75 ft for take-off and landing
91,000 sq yd single Marston Mat apron covered with asphalt
150 tents; prefabricated buildings for shops
1 temporary hangar
1500 personnel
Base supplied by land or water transport

AIRHEAD WATER BASE:

90 attack aircraft, tools, and spare parts
1 wooden ramp 200 ft x 75 ft for take-off and landing
91,000 sq yd single Marston mat apron covered with asphalt
250 tents
2300 personnel
Base supplied by 6 proposed water-based transport aircraft

SMALL AIRHEAD WATER BASE:

30 attack aircraft, tools, and spare parts
1 wooden ramp 200 ft x 75 ft for take-off and landing
30,000 sq yd single Marston Mat apron covered with asphalt
70 tents
767 personnel
Base supplied by 3 proposed water-based transport aircraft

NOTE: All personnel allowances include an appropriate amount of local defense.

Fig. 17. Requirements for Water Bases

Fig. 18. Aircraft Dispersed at Land Bases

It should be noted that the carrier is included in this analysis on a complementary basis rather than as a competitor. It is beyond the scope of this study to investigate the many additional factors significant to a relative comparison of carrier and surface basing systems.

B. DISPERSION AND VULNERABILITY COMPARISON

In this section important features that cause water bases to differ from land bases in their vulnerability to attack are indicated and discussed. The effects of atomic and conventional explosives are included in this analysis. Since a thermo-nuclear weapon can irreparably destroy either type of base, this type of weapon is not pertinent in this study of comparative vulnerabilities and is excluded from further discussion.

1. Dispersal of Aircraft at Land and Water Bases

The ideal dispersion pattern for parked aircraft is one where, due to sufficient separation, each parked aircraft is more efficiently attacked as a single independent objective rather than by area bombing the dispersal site. Dive bombing and fighter attack at minimum altitude are the types of attack generally directed against single aircraft, and dispersal beyond some minimum has little direct effect against these methods. The net gain from area bombing of the dispersal site obviously declines as the density of aircraft within the dispersal area decreases and ultimately is reduced to a value below the gain from types of attack directed against single aircraft.

Land bases.- Plans for land bases indicate that a 1500-foot separation between hardstands for parked aircraft is desired (Fig. 18). This degree of dispersal is, however, regarded as being too expensive. Planners have adopted as a reasonable compromise the idea of clusters of three heavy bombers or six medium bombers concentrated in rectangular areas. These rectangular areas are separated by 1500 feet.

This existing United States dispersion plan for land bases by no means presents the enemy with a situation where it is not economically advantageous to employ atomic weapons. Since the smaller yield weapons are estimated to cost approximately one-third the price of the attack bomber, an atomic attack probably cannot be avoided by dispersal. However the prevention of multiple lethal coverage by a single bomb may be an objective of dispersal. For [illegible] the separation necessary to accomplish this objective [illegible] miles, or considerably [illegible]

Fig. 19. Aircraft Dispersal at Water Bases

when the aircraft are shielded by natural features. When a sizable number of individual aircraft are separated by 2 or 3 miles, operational control would probably be prohibitably difficult and ground defenses badly weakened by dilution. A more practical optimum for aircraft dispersal might be a pattern of clusters of aircraft, each cluster separated by 2 to 3 miles and the aircraft within the cluster separated by 1500 feet.

Land-base dispersal is limited in part by terrain features and availability of real estate. Besides additional land costs, increased expenditures are necessary for a larger intra-base road and communications system, longer taxiways, and more expensive protection against enemy infiltration.

Water bases.- The somewhat linear dispersal of aircraft along a shore line, as shown in Fig. 19, reduces the number of aircraft covered by the lethal area of a single atomic bomb as compared with the usual aircraft dispersal at a land base. At a favorable site for a water base, it is very likely that the ideal in dispersion of aircraft is economically attainable because of the available physical resources. The aircraft dispersal area is the shore of the water body. The requirements for an interconnecting road and taxistrip system may be omitted and water transportation substituted. The water body may provide a partial barrier against infiltration, particularly when the water base is on one shore of a river.

The possibilities of dispersal afforded at a water base are far beyond those of any previous operational experience. It is conceivable, for instance, for the aircraft to be distributed along a twenty-mile segment of river shore line. This dispersal is particularly possible for bomber operations when sufficient warning can be given before take-off to prepare for the mission. Although greater dispersal of aircraft is attainable through water-base operations, it is not certain that a similar claim can be made for the dispersal of servicing facilities because of the interdependence of these activities.

An indirect benefit of wide dispersal is the increased ease of concealing aircraft from attackers. The attacker must spread his search effort over a greater area. Characteristics of the shore line may also favor concealment. If the shore line is wooded, the opportunities for concealment are increased. A steep sloping bank along the edge of the water may also hide as well as shield the hydroski aircraft. By scooping out the bank with earth moving machinery or by blasting, a lodging is quickly provided, and a cover that blends with the surroundings will furnish a high degree of concealment. On unpaved ground leading to its

A potential water-basing site for the hydroski attack aircraft is this lake in the Balkan Peninsula.

Fig. 20. A Water-Base Site of Limited Access

concealed location, the hydroski attack bomber will leave short tracks that are more easily obliterated than those from conventional landing gear.

Unless concealment is simultaneously accomplished, dispersal above a certain degree merely dilutes the defense. This is particularly true when the target defense consists of AA guns where dispersal reduces the gun coverage. With missile defense of air bases, the loss of defense density is much less because of the longer range of these weapons.

The topographical characteristics of the areas surrounding water bodies are apt to differ from areas in which land bases are located. At land bases, the runways, taxiways, and dispersal areas must be at the same elevation. An area that provides terrain suitable for a land base is apt to be an extensive plain. Here there are no natural features to provide shielding against blast and fragments or to provide obstacles against aircraft attacking at low level.

The low level attacker has an unlimited choice of approaches. This situation may be considerably altered at a well located water base. Besides furnishing shielding and concealment, steep banks restrict the direction of low level approach and raise the altitude for pull-up. Figure 20, showing limited access, is typical of naturally protected water-basing sites.

2. Special Vulnerability Problems of Water Bases Exposed to Atomic Attack

The proximity of the water body to the base exposes the aircraft and facilities to special types of damage not possible at land bases. This is due to atomic bursts on or below the surface of the water. Such bursts will cause a wave that may damage aircraft and facilities. Also the fall-out of water and the base surge following the burst are sources of radiological contamination of the water base. A third special vulnerability problem is the possible cratering of the floor of the water body, which might cause the aircraft to run aground.

Quantitative information relating to the effects of surface or underwater detonations are believed to be inadequate to do more than provide order-of-magnitude estimates. The available experimental data on underwater explosions include only one atomic fission detonation. Scaling from small charge experiments is considered to be an unreliable procedure for predicting these effects (Ref. 20).

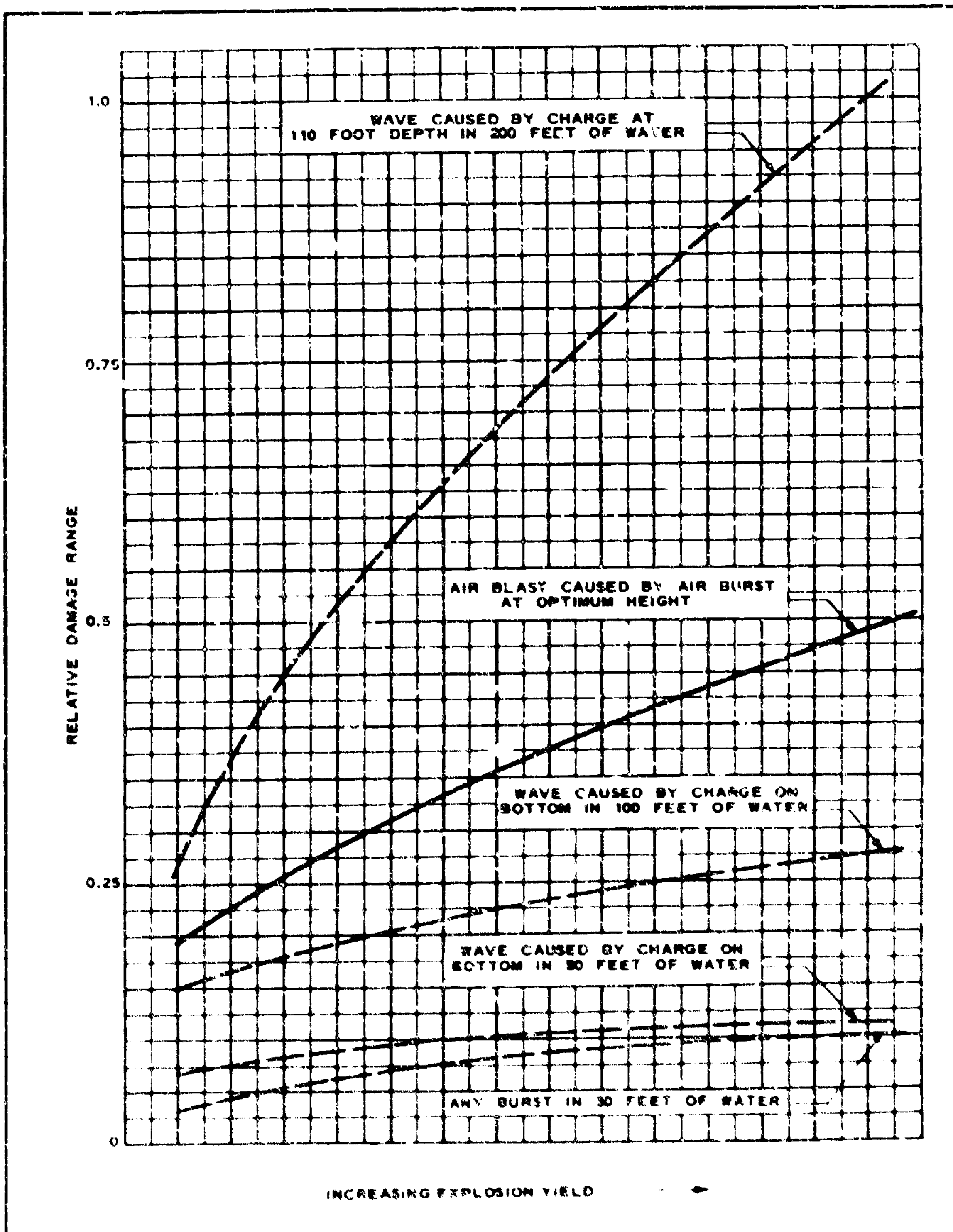

Fig. 21. Relative Effects of Air Blast and Wave Damage

The wave effect.- The wave phenomena accompanying a surface or underwater burst is described in Ref. 18. A deep water body adjacent to the base increases the vulnerability to wave damage. Figure 21 illustrates the relative effect of water depth on the ranges of wave damage. The minimum height of a wave that will damage aircraft and base facilities was estimated at 10 feet. No reduction in range has been taken for the decrease of wave height after the wave enters shallower water. Figure 21 also compares ranges of wave damage with the range of damage to aircraft from an air burst at optimum altitude. It is clear from this comparison that the damage from air blast is greater than the damage from waves in shallow water. In view of the wide dispersal of aircraft at a water base, it appears that if the depth of the water body is less than 100 feet, an underwater burst is not as efficient as an air burst against shore facilities.

Thus, a shallow water body adjacent to a water base does not add any likelihood of that base incurring greater physical damage than a land base under similar attack.

Radiological contamination.- Radiological contamination is not thought of as a primary means of reducing the effectiveness of an installation such as a land or water base. Radiological contamination is primarily a method of effecting personnel casualties rather than materiel damage and an aircraft base is primarily a concentration of valuable materiel. To optimize the degree of contamination, an underground or underwater burst is required. With this type of burst, blast and thermal effects are greatly reduced. Radiological contamination is thus a bonus effect for military targets that are not spread over too great an area where the blast loss of a single bomb can be afforded. With its wide dispersal, a water base does not offer the enemy this type of target.

It has been predicted that the area highly contaminated by an underground explosion would be smaller than that of an underwater burst. One reason is that the density of soil is greater than that of water and a smaller mass would be thrown into the air to descend at a distance from the explosion (Ref. 19). Comparison of results of one underground and one underwater burst does not clearly support this stand.

In an underwater burst, the initial gamma and neutron radiations are almost completely absorbed in a few yards of water. There is little neutron-induced activity from an underwater explosion and the radioactivity created has a short half-life. The radioactive material in the water will rapidly become ineffective because of the dilution due to mixing in water. To contaminate the shore, the fission products and induced radioactive elements must escape from the water and be deposited on the shore. For appreciable contamination, the underwater atomic explosion must be so near the shore that significant amounts of the fall-out of water and the base surge, consisting of a contaminated dense mist moving outward, will reach the adjacent land areas. The mechanics of base surge formation are not well understood. It is believed, however, that a base surge will not appear in a shallow water detonation.

The amount of induced radioactivity following an underground burst depends on the mineral content of the soil. The total radioactivity may be considerably more than that resulting from an underwater burst of the same yield. Also, if the bomb is accurately delivered, all of the radioactive material is deposited within the area of the base.

Thus it does not appear that the water body constitutes a potential radiological hazard to the water base, particularly if the water body is shallow and the base surge phenomenon is not present. The water body is not believed to offer the enemy a means of contamination superior to means existing at a land base.

Cratering the floor of the water body.- Craters on the floor of the water body caused by subsurface A-bomb bursts may be of practical significance to a water base because of crater lips that block take-off and landing areas. Since the hydroski aircraft does not sink more than a few inches when moving at a rate above the critical speed, only crater lips extending above the surface of the water are significant.

The dimensions of the crater depend partly on the geological characteristics of the bottom. A large single stage bomb detonated on the bottom in 50 feet of water will result in a crater diameter of between 1,500 and 2,00 feet, depending on whether the bottom is "hard" or "soft," and corresponding lip heights of 35 and 125 feet above the bottom (Ref. 20). In 100 feet of water the diameters and lip heights will be somewhat less and will continue to decrease with increasing depth of water. Although a weapon penetrating the bottom before detonation will cause a larger crater, it is unlikely that an enemy would be willing to sacrifice blast and thermal effects to crater the water body. He would lose the best effects of the weapon and disrupt the use of only a relatively small part of the water body. Even if the crater lip does extend above the water, it will not be necessary to reduce the lip when the water body provides an alternate operational area. A problem in removing the lip is presented by its highly radioactive content. Conventional explosives may be employed to reduce the lip.

The land-based counterpart of cratering the floor of the water body by A-bomb bursts is damaging the runways and taxiways. In general, the cratering of runways will cripple the operation of a field. This would impose greater repair requirements in both time and material than would be necessary for water bodies. Experience indicates that conventional bomb hits of about one bomb per acre are required to render a field temporarily inoperative (Ref. 21).

4. The Effect of the Water Body on Radar Bombing

As noted previously, radar reflects well from land but not from water. Hence, the contrast between water and land on a radar screen provides a good approach and an easy target for radar bombing. The radar reflectivity of paved or pierced-plank runways and taxiways at a land base also contrasts with surroundings but is less pronounced than land-water contrast.

The contrast provided by water and land bodies leads to improved bombing accuracy. This improvement has been estimated in Ref. 22 which classifies targets attacked through radar bomb sights as "easy" or "difficult". The circular probable error of bombs dropped by radar aiming at an "easy" target is approximately 25% less than for a "difficult" target. These categories are defined as follows:

1) Easy Targets

a) Targets with the aiming point within 8 miles of a land-water contrast feature such as a coastline, lake, or large river;

b) Industrial targets with prominent aiming points at least a mile outside the periphery of a large city, i.e., a city with an area of over 18 square miles; and

c) Targets within small cities, i.e., cities with an area of less than 18 square miles.

2) Difficult Targets

a) Targets in, or on the periphery of, large cities and which do not fall into the "easy" target category by virtue of land-water contrast.

It is clear that a water base is an "easy" target because of the land-water contrast. It is also clear that land bases would fall into the "easy" category if there were water bodies within 8 miles. In most cases the radar reflectivity of airfield features contrasts sufficiently with surrounding terrain so that land bases may also be considered favorable radar bombing targets.

TABLE 2

BASE LOGISTICAL REQUIREMENTS

Type of Base	Semi-Permanent		Temporary		Airhead		Small Airhead		Carrier
	Land	Water	Land	Water	Land	Water	Land	Water	
1. Number of Attack Aircraft	90	90	90	90	90	90	30	30	90
2. <u>Total Tonnage</u>									
Base Construction	17,451	11,655	11,099	5,254	11,124	5,384	7,497	1,891	45,000
Initial Supplies	5,307	5,307	2,776	2,775	5,307	5,307	1,769	1,769	5,307
Total Initial Supplies	22,758	16,962	13,875	8,030	16,431	10,691	9,266	3,660	50,307
Supplies per Month (20 sorties per aircraft)	9,197	9,197	9,182	9,182	9,197	9,197	3,066	3,066	9,222
3. <u>Tonnage per Mission Aircraft</u>									
Base Construction	193.9	129.5	123.3	58.4	123.6	59.8	249.9	63.0	500.0
Initial Supplies	59.0	59.0	30.8	30.8	59.0	59.0	59.0	59.0	59.0
Total Initial Tonnage	252.9	188.[illegible]	154.1	89.2	182.6	118.8	308.9	122.0	559.0
Supplies per Month	102.2	102.2	102.0	102.0	102.2	102.2	102.2	102.2	102.5

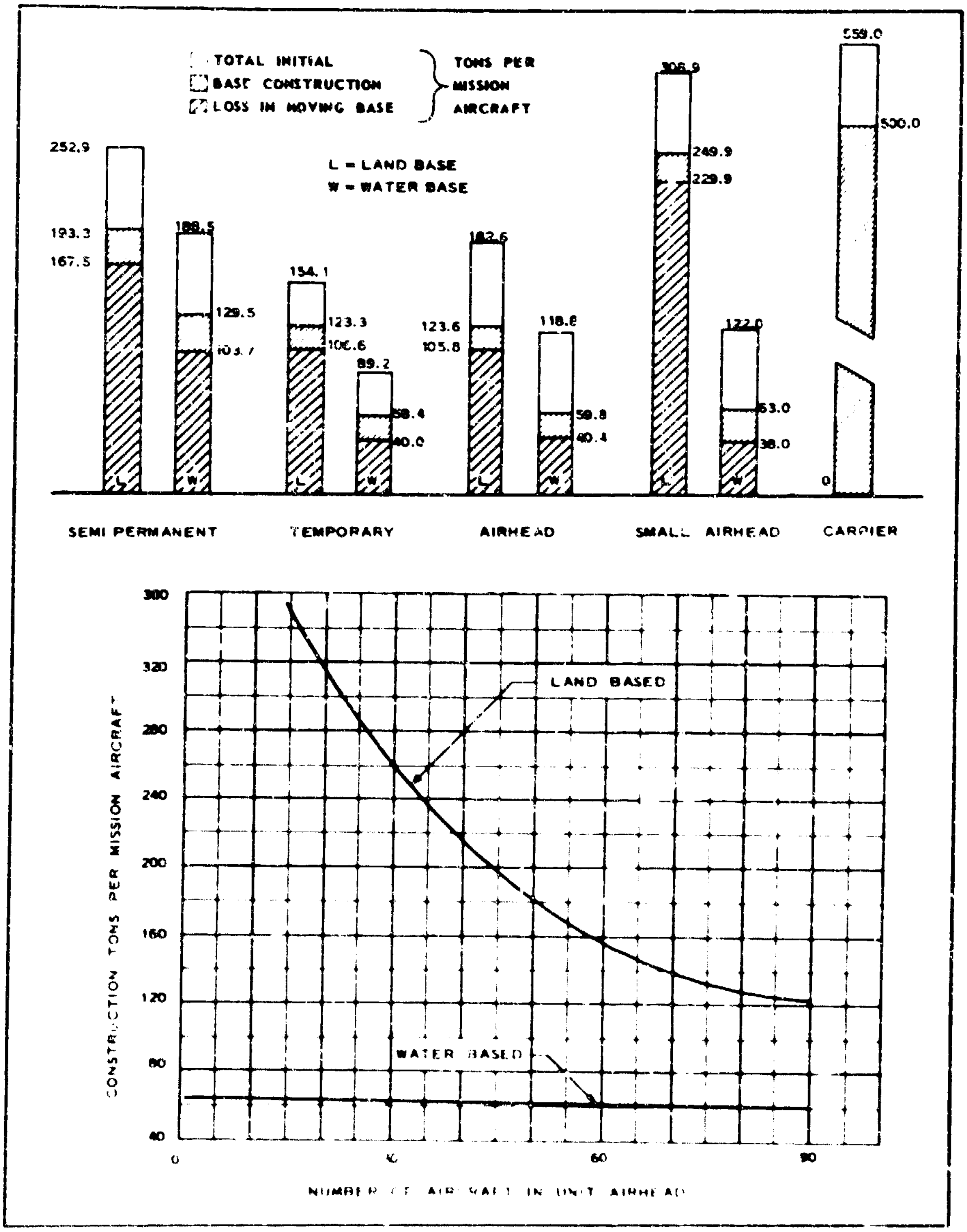

Fig. 22 — Base Logistical Requirements

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C. LOGISTICS ANALYSIS

1. Initial Tonnage Requirements

Semi-permanent base.- The initial tonnage required for a semi-permanent base is estimated with the aid of Refs. 23-27. The main constituents of base construction are runways, aprons, operational and maintenance equipment, and personnel facilities. In the semi-permanent type, the estimate for base construction of a land-based air group is 17,451 tons and for a water-based air group, 11,655 tons. The main difference in requirements between the two bases is that a very small runway is required for the water base. The initial supplies required, which include two weeks supply of petroleum products, ammunition, spare aircraft parts, and spare parts for other equipment, as well as personal gear and food, amounts to 5,307 tons and is equal for both versions. Total initial tonnage required for operations will be 22,758 tons for the land base and 16,962 tons for the water base. All tonnage requirements are summarized in Table 2 and shown graphically in Fig. 22

When stated in terms of requirements per mission aircraft, the base construction requirements amount to 193.9 tons per land-based aircraft and 129.5 tons per water-based aircraft. Total initial requirements amount to 252.9 tons for the land-based aircraft and 188.5 tons for the water-based aircraft.

Temporary base.- Apron space, living accomodations, and other facilities are cheaper in a temporary base than in a semi-permanent base. Initial tonnage required for the land base construction is 11,099 tons and for the water base construction, 3,254 tons. The initial supplies for the temporary base, estimated at 2,776 tons, are almost 50 per cent less than those for the semi-permanent base. The total initial tonnage required for the temporary land base is 13,875 tons and for the temporary water base, 6,030 tons.

Airhead base.- Base construction tonnage requirements for the airhead base are estimated at only slightly more than for the temporary base. The initial supplies for the airhead base are kept on the level of initial supplies for the semi-permanent base because an airhead may become more isolated than a temporary base. This requirement does not affect the comparison between the land-based and the water-based versions. The total initial tonnage required for the land-based version is [illegible] tons and for the water-based version, [illegible] tons.

Small airhead.- The small airhead is [illegible] for the use of [illegible] aircraft which [illegible] at the semi-permanent base, temporary base, or airhead base. The tonnage requirements, except for base construction and a very few equipment items, are reduced to one-third of the tonnage requirements of the large airhead base. The fact that the runway is identical in the two airheads results in appreciably higher tonnage requirements per mission aircraft for the land-based version of the small airhead than for the usual airhead. The total initial base tonnage required for the small airhead land base is estimated to be 7,497 tons compared with 1,891 tons for the small airhead water base. Initial supplies are 1,769 tons for both versions. The total initial tonnage required for the land-based version is 9,266 tons and for the water-based version, 3,660 tons. When stated in requirements per mission aircraft, the total initial tonnage for the small airhead is 308.9 tons for the land-based version and 122 tons for the water-based version. Relatively speaking, the land-based system suffers when the smaller units are compared (see Fig. 22).

Carrier base.- The comparison of carrier-based aircraft with land- or water-based aircraft operating inside a continent is not a fair comparison. In many cases, the carrier-based aircraft may be complementary to either the land-based or water-based aircraft rather than a rival of either one. The carrier has certain advantages, such as the ability to move at will through open seas and hence can attack coastal areas and contiguous inland areas that are within the radius of its aircraft. The carrier cannot get into the Volga River, whereas land-based or water-based aircraft may operate there. The land-based or water-based aircraft will not be able to attack a coastal area unless bases are secured within appropriate distances. Hence, it must be remembered that inasmuch as the carrier is included in this comparison, the comparison is of complementary methods of operation rather than rival methods of operation. It is assumed that a carrier displacing about 45,000 tons can base an air group of 90 attack aircraft. In this case, the initial tonnage will be 500 tons per mission aircraft.

2. Operating Supplies

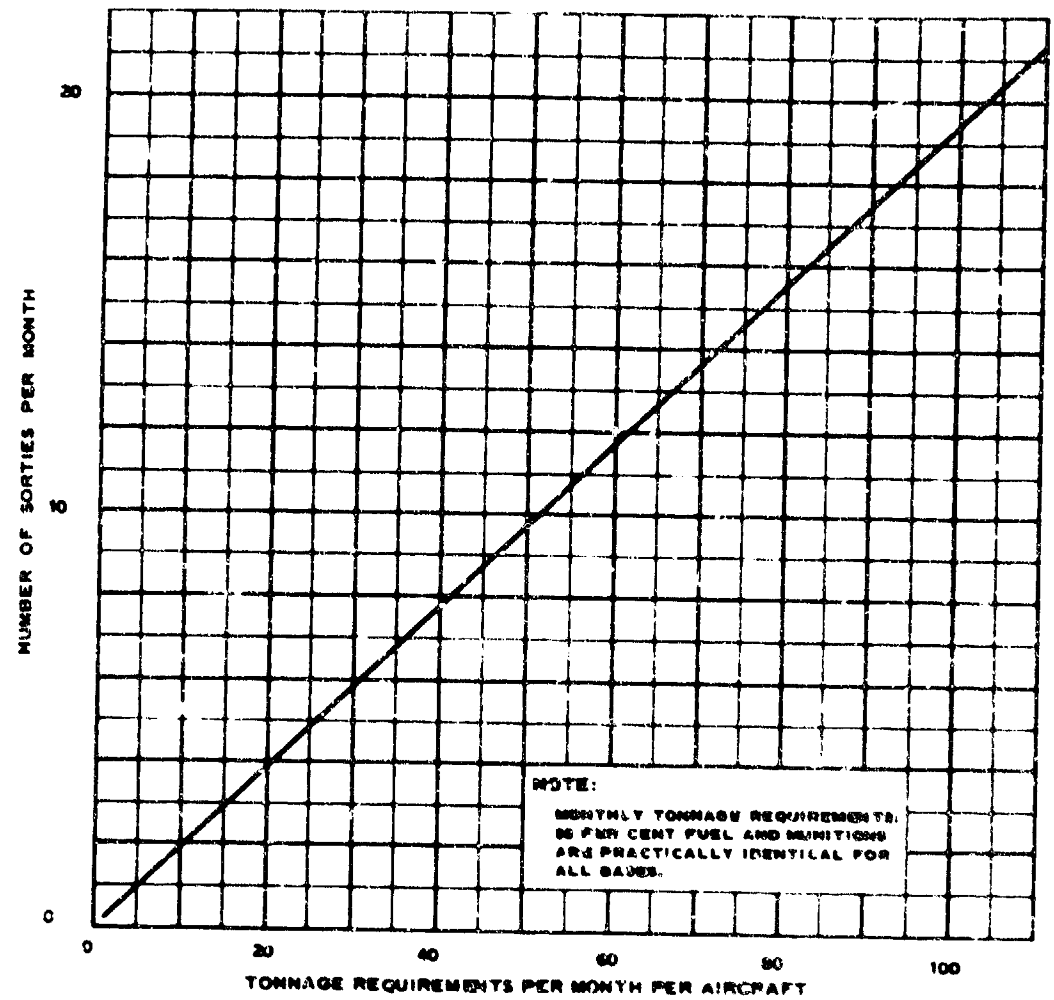
The logistics requirements while a base is in operation are largely dependent upon the ammunition and petroleum supplies needed. These supplies, shown in Fig. 23, will be identical at land and water bases and will depend upon the number of sorties flown. If 20 sorties per month are flown, the tonnage required per mission aircraft per month is estimated at 102.2 tons, and if 10 sorties are flown, the tonnage required is estimated to be [illegible] tons.

The number of tons per month required are important in determining the number of transport aircraft required to supply large and small airhead bases. Transport aircraft requirements are computed for 20 sorties per month flown by each mission aircraft. The land-based airhead can be supplied by [illegible] C-123 aircraft. This existing aircraft is specified because it is necessary to keep the

TABLE 3

MINIMUM LOGISTICS REQUIREMENTS - BASE MOVEMENT

Type of Base	Temporary		Airhead		Small Airhead	
	Land	Water	Land	Water	Land	Water
1. Number of Attack Aircraft	90	90	90	90	30	30
2. Total Requirements						
Minimum Tonnage Requirements to Commence Operations	9,343	2,600	9,543	2,800	7,412	933
Transport Vehicle and Design Payload	Truck 5 Tons	Truck 5 Tons	Aircraft 8 Tons	Aircraft 50 Tons	Aircraft 8 Tons	Aircraft 50 Tons
Number of Vehicles:						
1 trip	1,869	520	90	6	30	2
10 trips	187	52				
Empty Weight of Transport Aircraft, Tons	-	-	1,341	714	447	238
3. Requirements per Attack Aircraft						
Minimum Tonnage Requirements to Commence Operations	103.8	28.9	106	31.1	247	31.1
Number of Vehicles:						
1 trip	20.8	5.8	1	0.07	1	0.07
10 trips	2.1	0.6				
Empty Weight of Transport Aircraft, Tons	-	-	14.9	7.9	14.9	7.9



TO SUPPLY 80 ATTACK AIRCRAFT:

80 C-123 TRANSPORTS REQUIRED FOR LAND BASE

14.9 TONS TRANSPORT AIRFRAME PER ATTACK AIRCRAFT

6 WATER BASED TRANSPORTS REQUIRED FOR WATER BASE

7.9 TONS TRANSPORT AIRFRAME PER ATTACK AIRCRAFT

Fig. 23. Mission Operating Supplies for Attack Aircraft

TABLE 4

RECOVERABLE BASE TONNAGE

Type of Base	Semi-Permanent		Temporary		Airhead		Small Airhead		Carrier
	Land	Water	Land	Water	Land	Water	Land	Water	
1. Base Construction	17,451	11,655	11,099	5,254	11,124	5,384	7,497	1,891	45,000
2. Tonnage Recoverable	2,373	2,323	1,500	1,650	1,600	1,750	600	750	45,000
3. Tonnage Recoverable per Mission Aircraft	26.4	25.8	16.7	18.3	17.8	19.4	20	25	500
4. Tonnage not Recoverable	15,078	9,332	9,599	3,604	9,524	3,634	6,897	1,141	0
5. Tonnage not Recoverable per Mission Aircraft	167.5	103.7	106.6	40	105.8	40.4	229.9	38	0

runway requirement as simple as possible. The projected water-based transport aircraft described in Ref. 2 is assumed to supply the water base. Six of these aircraft will be required. For both types of bases, the mission requirements for the small airhead are reduced by two-thirds. The empty weight of transport aircraft required per mission aircraft, shown in Fig. 23 and Table 3, is 14.9 tons per mission aircraft for the land base and 7.9 tons for the water base.

3. Tonnage Recoverable

It is very important to consider the tonnage that can be salvaged when a base is moved. Tonnage that is salvaged reduces: 1) the weight of material that must be transported from the United States to foreign areas; and 2) reduces the cost of war to our national economy. In all of the bases examined, the runways, buildings, and ground construction work are not recoverable. The material recoverable when moving is primarily transportable equipment.

The tonnage recoverable and tonnage lost are summarized in Table 4. In a semi-permanent base, the tonnage not recoverable per mission aircraft is 167.5 tons for the land base and 103.7 tons for the water base. For the temporary base, corresponding figures are 106.6 tons and 40 tons, respectively. On the airhead base, they are 105.8 tons and 40.4 tons, respectively. On the small airhead base, the water-based aircraft compares more favorably than on any other type of base. Here, the tonnage lost per mission aircraft is 229.9 tons for the land base and 38 tons for the water base.

In this comparison the aircraft carrier is more economical than any other kind of base because it can be moved from one location to another with no loss of base construction or initial supplies. These data are illustrated in Fig. 22.

4. Summary

The tonnage required for the water-based attack system is consistently less than for the land-based system because of the smaller amount of surfacing necessary. The amount lost due to a base move is greatest for the land base. The relative advantage of the water-based system increases with a decrease in size of the air group.

In the airhead even the regular supplies impose a greater problem for the land base because of the limited size of transport that must land on the minimum runway prepared for attack aircraft.

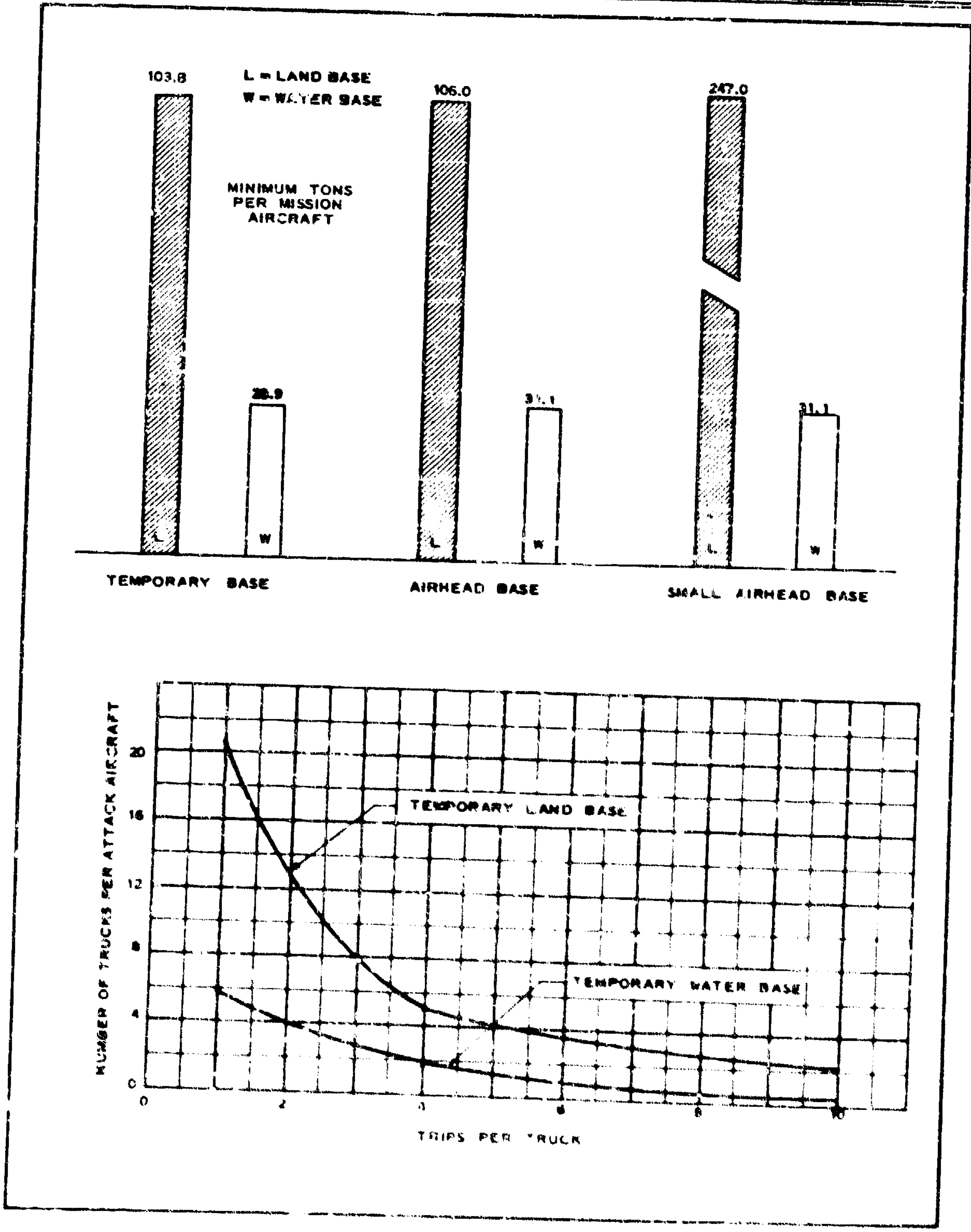


Fig. 24. Minimum Trucks and Tonnage to Commence Operations at a Temporary Base

D. SYSTEM FLEXIBILITY

The flexibility of this attack weapon system will depend upon the number of sites at which it can be based, the facility with which these bases can be moved, the number of available targets for the mission aircraft, the capability of using the aircraft effectively in case of emergency, and the ability to move in response to various types of enemy attack.

1. Base Availability

Ideally, the water at a water base must be deep enough to land the large transport aircraft that are capable of supporting the attack aircraft.

In the European land mass there are:

1) Over 3,000 lakes of sufficient size and depth for major marshalling areas. Large water-based transport operations would be supported by water-based attack aircraft;

2) An unsurveyed but large number of additional lakes suitable for the attack aircraft alone;

3) 18.000 miles of rivers and canals having stretches of sufficient size and depth to meet gross-weight requirements of the water-based transport; and

4) 35,000 miles of coastal waters containing hundreds of [illegible] suitable for amphibious operations.

2. Base Mobility

A base is considered to be moved when full scale operations in all kinds of weather have been established. It is recognized that partial operations could be carried on from land bases or water bases prior to the time when full operations can be conducted. Temporary landing strips can be [illegible] when the usual runways are ready for operation. However, it is believed that the comparison between land bases and water bases will be on a firmer basis if the comparison is made on the attainment of full operations rather than upon some arbitrary standard or partial operations.

The tonnage requirement for each of the types of bases was restudied in order to estimate the tonnage required to commence operations. These estimates are summarized in Table [illegible] and illustrated in Fig. 34. The maximum tonnage required per [illegible] aircraft to establish operations for the temporary land base is estimated to be 103.8 tons and for the temporary water base 28.9 tons. In the airhead, the corresponding figures are 106 and 31.1 tons, respectively. In the small airhead, the minimum tonnage requirements are 247 tons and 31.1 tons, respectively. It is considered that a semi-permanent base will not be constructed when frequent moves are likely.

Temporary base.- In the comparison, temporary bases are moved by truck. The number of trucks required will be less if sufficient time can be expended to permit the trucks to make more than one trip. In this study, the requirements were investigated when the trucks make one trip and when they make 10 trips. These data, summarized in Table 3 and Fig. 24, show that if the move is made in one trip, an average of 20.8 five-ton trucks per mission aircraft will be required to move a land base, and 5.8 five-ton trucks per mission aircraft will be required to move a water base. If time can be spent to permit 10 trips per truck, the number of trucks will be reduced to 2.1 and 0.6, respectively.

The time required to move a base from one site to another is measured from the time that a decision is made to make this move to the time when the base is fully operational. The time required is investigated for a move with trucks making one trip or 10 trips, for distances of 200 nautical miles or 400 nautical miles. In comparing the movement of the temporary base, the requirements for planning and preparation, including initial loading, were estimated to be 24 hours for both water and land bases. The time in transit will vary with the distance and the number of trips, but will be the same for both types of bases. It is estimated that the runway can be constructed and made available for operations in 360 hours. The total time required to achieve full operations is not necessarily the sum of moving and construction times, since much of the moving can be accomplished while the runway is being constructed.

The total time required versus the number of trucks required is illustrated in Fig. 25 and the total time required versus the distance moved is shown in Table 5 and Fig. 26. These comparisons show that the water bases are capable of more rapid movement than the land bases. For a base move of 200 nautical miles, it is estimated that the land base can be moved and made available for operation in [illegible] hours at one trip per truck compared with 48 hours for the water base. If 10 trips per truck are made the time required is 408 hours compared with [illegible] hours. When the distance moved is 400 nautical miles, the time required for the land base when one trip is made per truck is [illegible] hours and for the water base, 60 hours. When 10 trips per truck are made, this comparison is [illegible] hours and 480 hours, respectively.

Airhead base.- The comparisons of time for airhead establishment in Fig. 26 show that the water-based version has an advantage over the land-based version and that the time requirements are identical for the large airhead and the small airhead. The number of transport aircraft attached to each tactical air unit is considered to be determined by the requirement for operational supplies rather than by the requirement for base movement. For the airhead and the small airhead it is estimated that 390 hours are required for a 200 nautical-mile move of the land base compared with 40.3 hours for the water base. If this move is 400 nautical miles, these figures are 392 and 44.9, respectively.

Carrier.- Movements of aircraft carriers can be made in much shorter time. Assuming an average speed of 20 knots, a carrier can move 200 nautical miles in 10 hours and 400 nautical miles in 20 hours. No initial preparation time for runway construction is involved.

Enemy interference.- Movements of land and water bases involve many logistic problems and are time consuming. In this analysis, possible attrition to the transport aircraft and trucks making the movement has not been considered. If attrition rates are significant, the costs of such moves may be prohibitive. If enemy attack on these lines of movement becomes important, the comparison will favor the water-based aircraft because of lower tonnage requirements.

3. Effective Action in Strategic Emergencies

In cases where it is desirable to concentrate many tactical aircraft in a relatively small area, such as bringing all the tactical air wings in western Europe to bear upon one sector, effective mobility will be required. Since the water-based system is more mobile than the land-based system, these bases could be rapidly moved from existing sites to a concentrated area for operations. And since there are practically no areas in Europe where adequate water bases are not available within the radius of this aircraft from enemy targets, it appears that the water-based attack aircraft possesses the capability of maximum concentration whenever strategically necessary.

4. Effective Movement in Response to Attack

Here again, mobility is of prime importance. If the bases are subject to attack from enemy tactical aircraft, they can be moved out of range of the enemy bases more easily and more quickly if they are water based than if they are land based. If the attack is from advancing land troops, the water base can be moved faster than the land base and little will be left for the enemy to use. In either case, the aircraft themselves could be evacuated with equal speed and flown to fields in the rear. If the attack is

TABLE 5

TIME FOR BASE MOVEMENT - HOURS

Type of Base	Temporary		Airhead		Small Airhead		Carrier
	Land	Water	Land	Water	Land	Water	
1. Initial Preparation	24	24	24	24	24	24	0
2. Time in Transit, Move 200 Nautical Miles							
1 trip	12	12					10
10 trips	228	228					
*By Transport Aircraft			33	16.3	77.1	16.3	
3. Time in Transit, Move 400 Nautical Miles							
1 trip	24	24					20
10 trips	456	456					
*By Transport Aircraft			50.2	20.9	117.2	20.9	
4. Runway Availability	360	12	360	12	360	12	0
5. Minimum Time Requirements:							
Move 200 Nautical Miles:							
1 trip	396	48					10
10 trips	408	252					
*By Transport Aircraft			390	40.3	390	40.3	
Move 400 Nautical Miles:							
1 trip	408	60					20
10 trips	528	480					
*By Transport Aircraft			392	44.9	392	44.9	

*The same number and type of aircraft are used to move the base as are used to supply the base.

NOTE: "Minimum Time Requirement" is not always the sum of the elements since activities may overlap.

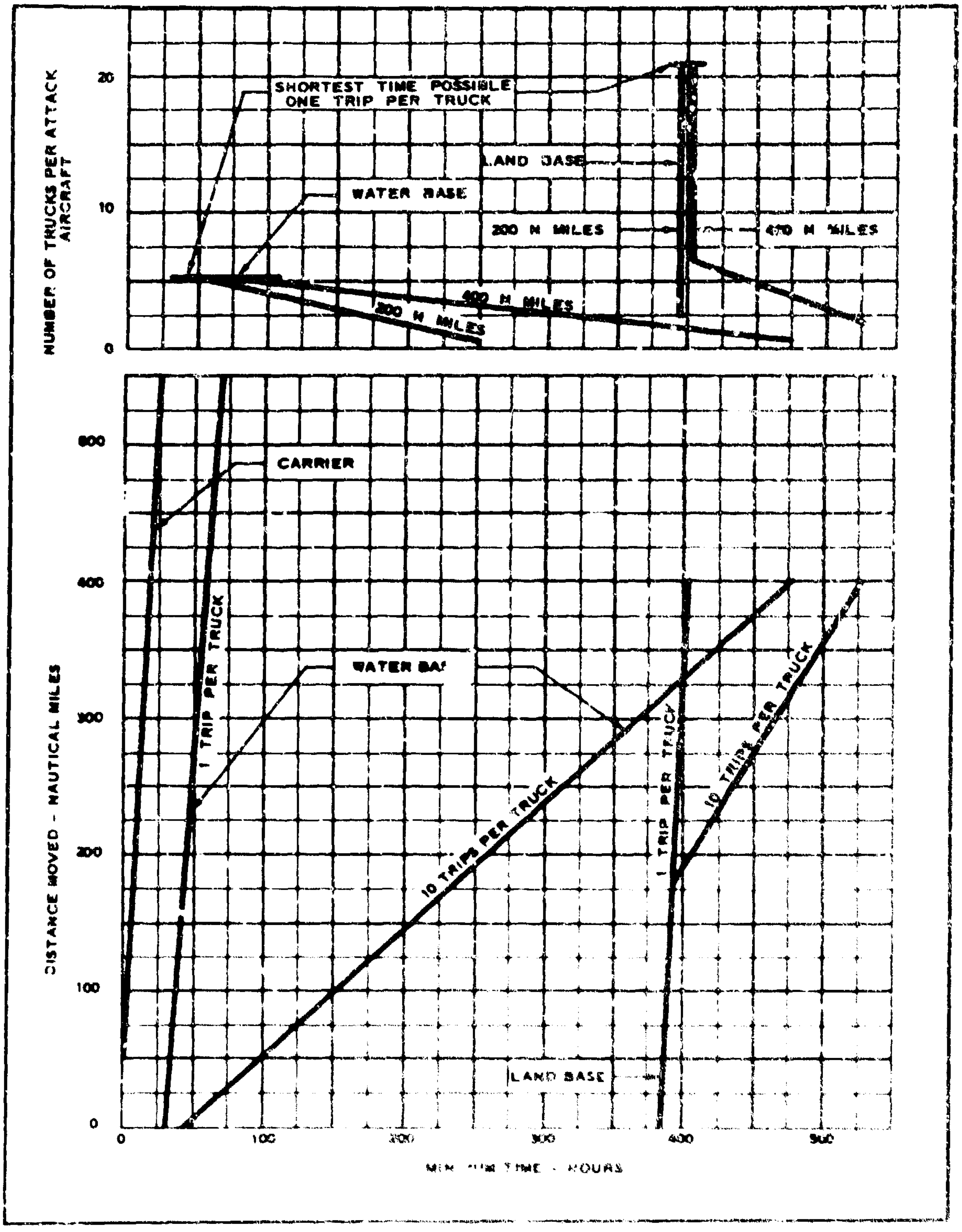


Fig. 2[illegible]. Time for Temporary Base Movement

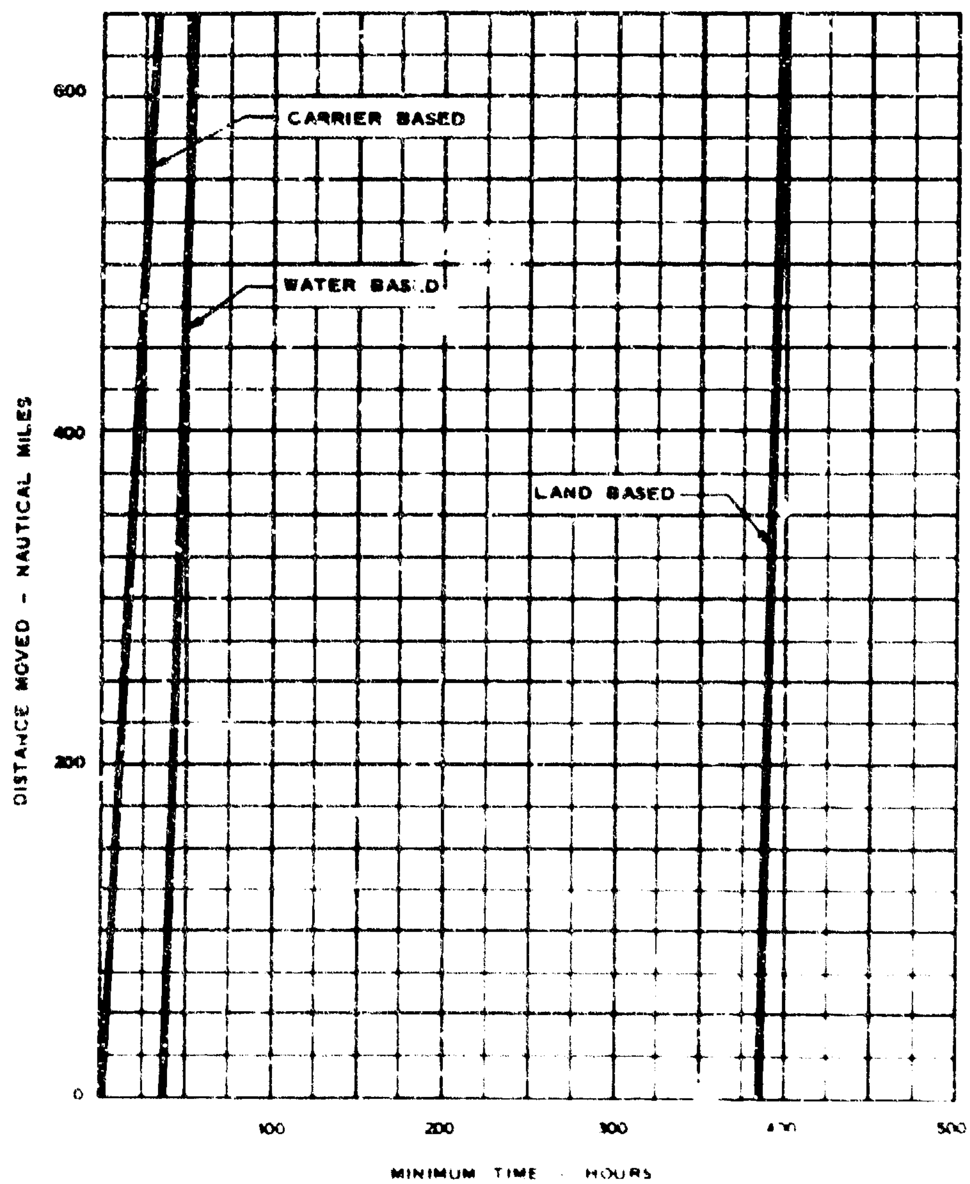


Fig. 26. Time for Airhead Establishment

coming from saboteurs who are in the area and if the aircraft are parked in one unit, the water bases have less area to be guarded by security fences or other devices. If the water-based aircraft are widely dispersed, then possibly they would require the same area to guard as would the land-based aircraft. So from this aspect, the water bases may have an advantage over land bases.

5. Summary

Advantages to be gained from flexibility depend upon base mobility more than any other factor. The water base can be moved from one spot to another with greater facility than the land base. The main reason for this advantage is because of the small runway requirements of the water-based aircraft. The superior mobility of the water base over the land base will lead to more effective action against enemy targets, against enemy advances, and against areas where it is desired to use all available aircraft.

F. COST ANALYSIS

This section considers the costs associated with the establishment and operation of the basing systems described previously and illustrated in Figs. 16 and 17.

1. Base Construction

Semi-permanent bases.- Semi-permanent land bases are estimated to cost $[illegible] million each and water bases $[illegible] million each, the difference being primarily that runway requirements are very small in the latter installations. This amounts to $[illegible] per mission aircraft for the land base and $[illegible],000 per mission aircraft for the water base. All base costs, summarized in Table [illegible] and Fig. [illegible] are computed with [illegible] Ref. 23 [illegible].

Temporary bases.- For the temporary land base, the costs are $[illegible] million compared with $[illegible] million for the water base. [illegible] amounts to $110,000 per mission aircraft for the land base and $[illegible] per mission aircraft for the water base.

Airfield bases.- [illegible] estimated to cost $[illegible] million compared with $[illegible] million for the water base. This amounts to $[illegible] per mission aircraft for the land base and $[illegible] per mission aircraft for the water base.

Small airfield base.- The small airfield, having a runway equivalent [illegible] and having [illegible] as many aircraft, will cost $[illegible] compared with $[illegible] for the water base. This amounts to $[illegible] land base and $[illegible] water base.

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TABLE 6

INITIAL BASE COSTS - MILLIONS OF DOLLARS

Factors Affecting Initial Costs	Semi-Permanent		Temporary		Airhead		Small Airhead		Carrier
	Land	Water	Land	Water	Land	Water	Land	Water	
1. Number of Mission Aircraft	90	90	90	90	90	90	30	30	90
2. Total Cost									
Base:	20.2	15.9	10.7	6.8	11.0	7.6	6.9	3.9	150.0
Value Saved	2.6	2.7	1.8	1.9	1.8	2.2	0.7	0.9	150.0
Value Lost	17.6	13.2	8.9	4.9	9.2	5.4	6.2	3.0	0.0
Attack Aircraft	62.7	62.7	62.7	62.7	62.7	62.7	20.9	20.9	62.7
Transport Aircraft					67.3	34.5	22.4	11.5	
Personnel, Training, and Traveling	23.6	23.6	20.1	20.1	23.6	23.6	7.9	7.9	28.8
Initial Supplies	2.4	2.4	1.2	1.2	2.4	2.1	0.8	0.8	7.2
Total	108.9	104.6	94.7	90.8	167.0	130.8	58.9	45.0	248.7
3. Costs Per Mission Aircraft									
Base:	0.225	0.177	0.119	0.076	0.122	0.084	0.231	0.130	1.667
Saved per Mission Aircraft	0.029	0.030	0.020	0.021	0.020	0.024	0.024	0.030	1666.7
Lost per Mission Aircraft	0.196	0.162	0.099	0.055	0.102	0.060	0.207	0.100	0.0
Attack Aircraft	0.696	0.696	0.696	0.696	0.696	0.696	0.696	0.696	0.696
Transport Aircraft					0.748	0.383	0.748	0.383	
Personnel, Training, and Traveling	0.262	0.262	0.223	0.223	0.262	0.262	0.262	0.262	0.320
Initial Supplies	0.027	0.027	0.013	0.013	0.027	0.027	0.027	0.027	0.030
Total	1.210	1.162	1.051	1.008	1.855	1.452	1.964	1.498	2.753

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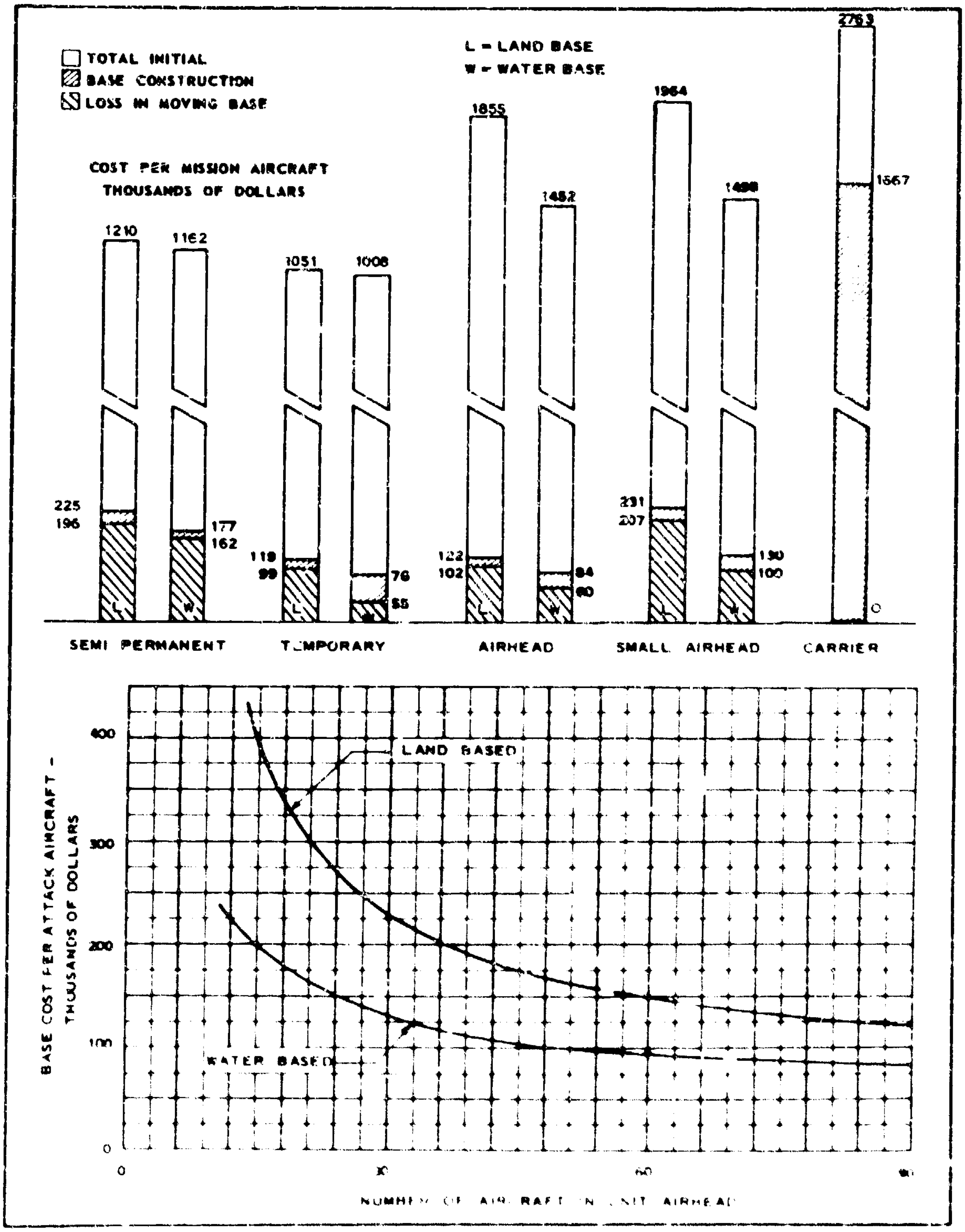

Fig. 27. Base Costs

Carrier.- The 45,000-ton aircraft carrier is estimated to cost $150 million at present replacement costs. This amounts to $1,667,000 per mission aircraft.

Overseas base construction is listed as one of six critical items in wartime planning. The water-based aircraft show a considerable advantage over land-based aircraft with respect to original base construction costs. This advantage is of even greater importance since the savings are cumulative when bases are moved from one site to another.

2. Total Value at a Base

In this study, each attack aircraft is estimated to cost $696,000 regardless of whether land based or water based. This estimate is based upon the assumption that a large number of these aircraft will be manufactured.

The personnel requirements are estimated to be 2,300 for the semi-permanent base, 1,500 for the temporary base, 2,300 for the airhead base, and 767 for the small airhead base. These requirements are estimated to be identical whether for land base or water base. Personnel training and traveling costs are estimated with aid of Ref. 27 to be $23.6 million for the semi-permanent base and airhead base, $20.1 million for the temporary base, and $7.9 million for the small airhead base. When estimated per mission aircraft, personnel costs are $262,000 for the semi-permanent base, airhead base, and small airhead base, and $223,000 for the temporary base.

Initial supplies are estimated on a two weeks basis to cost $2.4 million for the semi-permanent base and airhead base, $1.2 million for the temporary base, and $0.8 million for the small airhead base.

To transport supplies to the land-based airhead, 90 existing low-tire-pressure and low-wheel-loading aircraft costing $67.3 million will be required. This type is used because air transport is necessary in the construction stages. At the water-based airhead, the projected transport can be used (Refs. 1 and 2). Six of these aircraft costing $34.5 million will be required. Transport requirements for the small airheads are one-third of those for the airheads.

When the total value at a base is computed, the difference between the water base and the land base is not very high. It is $108.9 million for the semi-permanent land base and $104.6 million for the semi-permanent water base. Reduction of base facilities and initial supply level leads to a lower total value for the temporary base, $94.7 million and $90.8 million, respectively.

The total value at a land-based airhead is $167 million compared with $130.8 million for the water-based airhead. For the small airhead, these figures are $58.9 million and $45 million, respectively.

When the carrier is included, it is found that the total value is much higher, namely $248.7 million for an air group. When stated on the basis of value concentration per mission aircraft, the carrier is highest with $2.76 million. In all cases, the water-based aircraft is below that of the land-based aircraft (see Table 6 and Fig. 27).

3. Value Lost When Base is Abandoned

The value lost when a base is abandoned, summarized in Table 6 and Fig. 27, is important in determining the practicality of moving a base to another site. The materials recoverable from both types of bases are vehicles, transportable equipment, and supplies. Construction of buildings and labor expended on the site are, of course, lost. It is estimated that $17.6 million will be lost when a semi-permanent land base is abandoned, compared with $13.2 million for a semi-permanent water base. The value lost is $8.9 million for a temporary land base and $4.9 million for a temporary water base. For the airhead base, the value lost is $9.2 million compared to $5.4 million. At the small airhead base, it is $6.2 million compared with $3 million.

In comparison, the carrier loses nothing when moving from base to base unless attrition due to enemy action is introduced. Its only cost for moving is fuel. Since movement is in effect part of the designed operation of the carrier, it can be said that movement is almost costless.

4. Mobility Costs

The annual base costs are compared when the base is stationary and when the base has 10 moves a year. From a practical standpoint, it is unlikely that a semi-permanent base would be moved and if a move were made from a semi-permanent base, it would be to another base which would be a temporary structure. When this move is made, the cost of making a move equals the cost of construction of the base, less salvage from the old base, plus transportation. Except where attrition from enemy action is important, transportation costs are almost negligible.

The cost of moving a base 10 times a year is shown to be $[illegible] million for a temporary land base compared with $49 million for the temporary water base (Table 7). The airheads are estimated to cost $93.[illegible] million for 10 moves for the land base

TABLE 7

ANNUAL BASE COSTS - MILLIONS OF DOLLARS

Factors Affecting Annual Base Costs	Semi-Permanent		Temporary		Airhead		Small Airhead		Carrier
	Land	Water	Land	Water	Land	Water	Land	Water	
1. <u>Total Costs</u>									
Original Base Cost	20.2	15.9	10.7	6.8	11.0	7.6	6.9	3.9	150.0
Annual Cost - No Moves	10.1	8.0	10.7	6.8	11.0	7.6	6.9	3.9	37.5
	(2 years depreciation)		(1 year depreciation)		(1 year depreciation)		(1 year depreciation)		(4 years depreciation)
Cost of Ten Moves (Nonrecoverable and Transportation)	176.2	124.1	89.2	42.2	92.2	42.2	62.2	25.1	0.2
Annual Cost - Ten Moves	186.3	132.1	99.9	49.0	93.2	49.8	69.1	29.0	37.7
2. <u>Costs Per Mission Aircraft</u>									
Annual Base Costs per Mission Aircraft, No Moves	0.112	0.095	0.119	0.080	0.122	0.081	0.231	0.126	0.417
Annual Base Costs per Mission Aircraft, 10 Moves	2.070	1.474	1.110	0.548	1.036	0.550	2.073	0.936	0.419

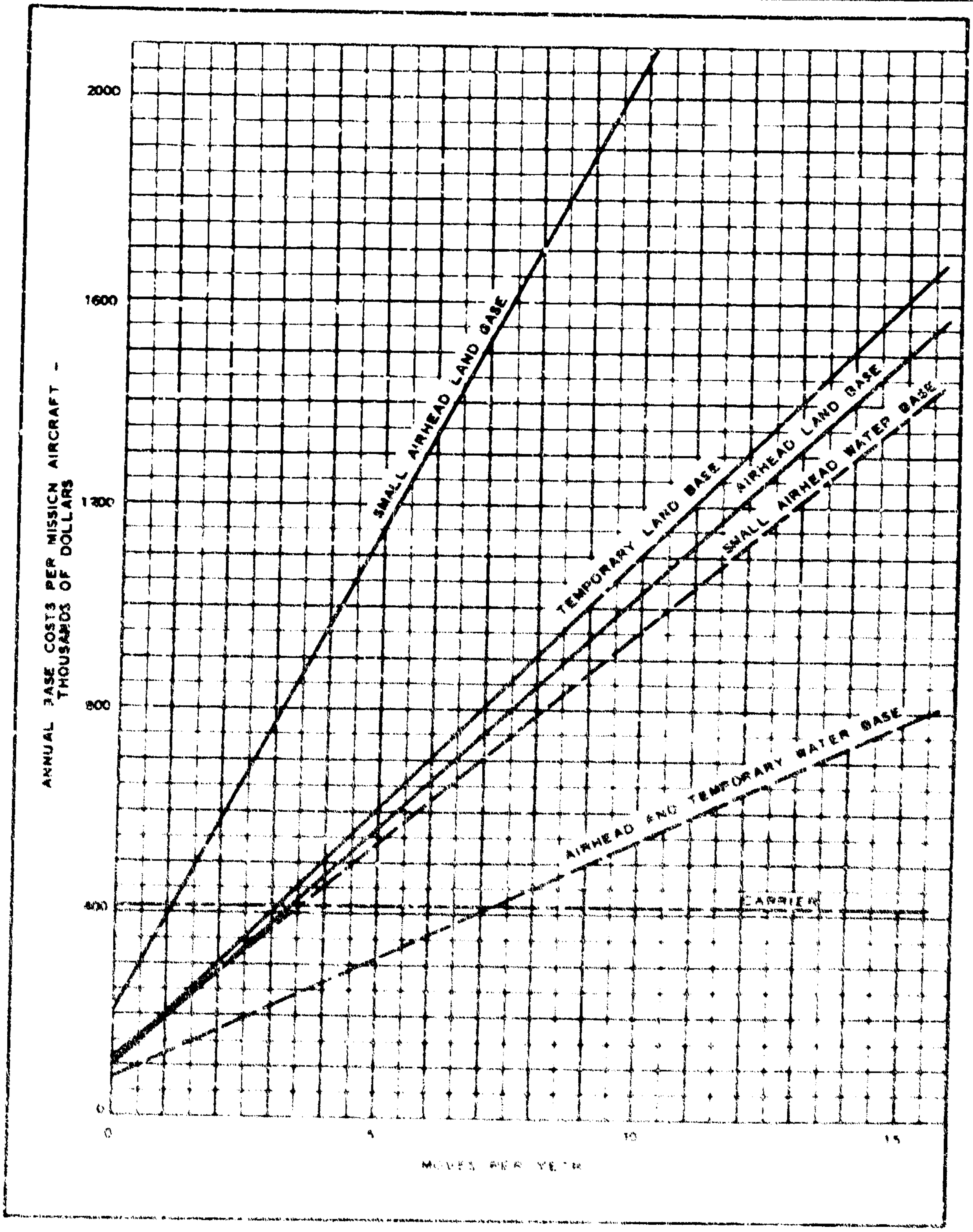

Fig. 28. Annual Base Costs vs Moves Per Year

compared with $49.8 million for the water base. With small airheads, the comparison is proportionately more favorable to the water base where the cost of 10 moves is estimated to be $69.1 million for the land base compared with $29 million for the water base. The comparative cost for making moves with the assumed carrier depends largely upon the amortization rate of the carrier itself. This is a four year period which would mean a cost of $37.7 million a year. Costs of mobility, summarized in Table 7 and Fig. 28, are lower in all cases for the water-based aircraft than for land-based aircraft and lower yet for the carrier.

5. The Size of the Unit

It is possible to domicile the water-based aircraft in small units for purposes of dispersion without being subject to rapidly rising base construction costs per mission aircraft (see Fig. 20). Since runway costs are equal for either a group of 90 aircraft or a squadron of 30 aircraft, the base costs per mission aircraft are greatly increased when the number of land-based aircraft is reduced from 90 to 30. The increase for the water-based aircraft is much less.

6. Cost Summary

Bases for the hydroski water-based aircraft cost less than bases for the conventional land-based aircraft, primarily because of differences of the runways. Since runways are not recoverable, the value lost when a base is abandoned is considerably more for the land base than the water base. For these reasons, the cost of mobility is much less for the water base than for the land base. The carrier base is more expensive than a land base or water base with respect to initial costs. However, the costs of moving are negligible for the carrier so that when a high degree of mobility is required the carrier becomes the cheapest base.

VI. CONCLUSIONS AND RECOMMENDATIONS

From the analysis of the potential of water-based aircraft for attack missions, it is concluded that:

1. The water-based attack system offers the greatest flexibility of operation;

2. The land-based systems require two to four times the tonnage for establishment and a much longer time to build;

3. The required high performance in the air can be obtained equally well with water- or land-based aircraft,

4) The costs in time, manpower, and dollars are lower for water bases, especially when frequent base moves are desired, and

5. The advantages of water basing are relatively much greater for smaller size air groups.

Although the current experiences with [illegible] aircraft indicate that the water operation is feasible, further technical developments should be encouraged.

It is recommended that:

1. The [illegible] water entry and exit [illegible] date.

2. [illegible]

3. [illegible]

4. [illegible]

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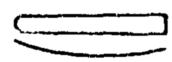
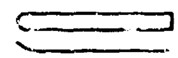
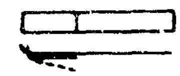
APPENDIX A

HYDROSKI EVALUATION

HYDROSKI EVALUATION

AIRCRAFT	J3 CUB			
REFERENCES	Ref. 31			
SKI DESIGNATION	PS-1	PS-2	PS-3	FS-3A
CONFIGURATION				
TYPE INSTALLATION:				
NUMBER OF SKIS	2	2	2	2
BUOYANT OR NON-BUOYANT	Non-Buoyant			
WHEELS				
RETRACTABLE	No	No	No	No
ADJUSTABLE TRIM	Trim Loaded by Bungee C[illegible]ds			
TYPE OF STRUTS	Standard Flexible			
GROSS WEIGHT OF AIRCRAFT	1000 lb	1000 lb	1000 lb	1000 lb
WEIGHT OF SKIS (est)	52 lb*			
WEIGHT SKIS, FOILS AND STRUTS (est)				
UNIT LOADING, $\frac{GW}{\text{ski area}}$	87 lb/sq ft			
MAXIMUM LOAD FACTORS				
MAXIMUM IMPACT LOADS				
MAXIMUM IMPACT ACCELERATIONS				
MAXIMUM IMPACT MOMENTS				
ASPECT RATIO $\frac{\text{width}^2}{\text{area}} = \frac{\text{span}}{\text{MAC}}$	5.75			
SKI AREA (total)	11.5 sq ft			
SKI VOLUME (est)	3.8 cu ft*			
VOLUME OF RETRACTED ASSEMBLY (est)	5.30 cu ft*			
SKI DIMENSIONS (over-all)	1 ft x 6 ft			
LIFT DRAG IN WATER				
TRIM AND ADJUSTMENT RANGE	-15°, to -4°			
WATER STALL SPEED (or unport speed)	14.8 Knots	10.2 Knots		
WATER TAKE-OFF SPEED	35 Knots	35		
TAKE-OFF TIME (and wind velocity if other than 0)				

*Values estimated by The Glenn L. Martin Company formula for ski weight (Appendix B)

W = With

W O = Without

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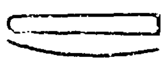
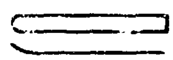
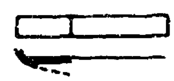
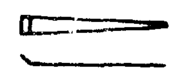
THE GLENN L. MARTIN COMPANY
BALTIMORE, MARYLAND

...TION

	J3 CUB Ref. 31				
	PS-1	PS-2	PS-3	FS-3A	PS-4
					
	2 Non-Buoyant No Trim Loaded by Bungee C...ds Standard Flexible	2 No	2 No	2 No	2 No
(est)	1000 lb 52 lb* 87 lb/sq ft	1000 lb	1000 lb	1000 lb	1000 lb
...S					
...Y (est)	5.75 11.5 sq ft 3.8 cu ft* 5.30 cu ft* 1 ft x 6 ft				
	-15', to -4', 14.6 Knots 35 Knots	10.2 Knots 35			4.1 at 12° Trim

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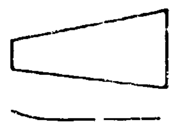
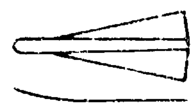
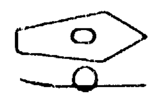
PS-5 	PS-5A 	PS-7 	PA-11 CUB Ref. 8 PS-14 
2 Standard Wheels No	2 No	2 Non-Buoyant No	2 Non-Buoyant Standard Wheels No Yes Standard CUB Flexible
1000 lb 76 lb* 43.5 lb/sq ft	1000 lb	1000 lb	1355 lb 63 lb, 71 lb* 85 lb 90 lb sq ft
			3.5 g*
1.62 23 sq ft 12.4 cu ft* 22.9 cu ft* 2 ft - 10 in. x 6 ft - 0 in.			1.73 15 sq ft 7.[illegible] cu ft* 17 cu ft* 2 ft - [illegible] in. x 6 ft - [illegible] in.
10 Knots 35 Knots 6 Sec			[illegible] to [illegible] in Thrust Line 9 Knots 33 Knots

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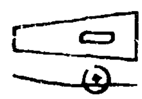
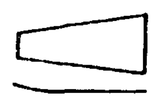
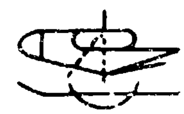
STINSON OY Ref 31		CESSNA OE	NAVION AAE
PS-5	PS-5A		
			
2	2	2	3
Non-Buoyant	Non-Buoyant	Non-Buoyant	
16 in. Diameter Wheels			
No	No	No	No
Yes	Yes		
Standard + 6 in. Extension	Standard + 6 in. Extension	1 Spring Steel Strut	1 Standard Oleo (Each Ski)
2050 lb	2050 lb	2400 lb	2850 lb
83 lb, 96 lb*	83 lb, 96 lb*	60 lb	Approximately 75 lb
119 lb	119 lb	100 lb	
89 lb/sq ft	89 lb/sq ft	145 lb/sq ft	
3.5 g*	3.5 g*		
1.62	1.62	1.33	
23 sq ft	23 sq ft	16.6 sq ft	
12.4 cu ft*	11.5 cu ft*		
19.2 cu ft*	18.8 cu ft*		
2 ft - 10 in. x 6 ft - 0 in.	2 ft - 10 in. x 6 ft - 0 in.	30 in. x 72 in.	Main 30 in. Mean x 84 in. Nose 30 in. Wide x 36 in.
4.7	8.6		
		2 Position 16 - 30 Range	2 Positions
12.5 Knots	11.5 Knots		
43.5 Knots	43.5 Knots		

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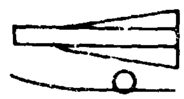
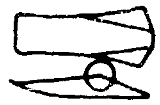
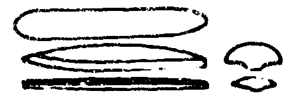
SNJ-5C		(NACA Tank Test)
Ref. 31	Ref. 8	Ref. 32
PS-6	PS-12	
		A B 
2	2	2 Types (A & B)
		Buoyant
14.5 in. Diameter Wheels	Standard Wheels	
No	No	No
Yes	Adjustable Trim Strut	
Standard SNJ Oleo	Extension to 4.5 in. Restricted Oleo	Rigid Struts with Fairing
5050 lb	5865 lb	8000 lb
208 lb*	175 lb, 153 lb*	192 lb, 134 lb*
	305 lb	297 lb
99 lb/sq ft W/ flaps, 196 lb/sq ft W/O flaps	215 lb/sq ft W/ flaps, 362 lb/sq ft W/O flaps	383 lb/sq ft
		3.5 g*
8.23 W/O Flaps; 1.41 W/Flaps	4.0 W/O Flaps, 3.0 W/Flaps	Approximately 3.1
25.8 sq ft; 50.8 sq ft	16.2 sq ft; 27.2 sq ft	A 20.8 sq ft | B 20.4 sq ft
18.1 cu ft*	14.7 cu ft*	13 cu ft* | 9.4 cu ft*
26.4 cu ft*	32.2 cu ft*	37.5 cu ft* | 23.5 cu ft*
W/O Flaps 1 ft - 3 in. x 10 ft - 4 in.	W/O Flaps 1 ft - 7 in. x 7 ft - 11 in.	1 ft - 10 in. x 6 ft - 4 in. (each)
		3.62 Maximum
-14 to + 4 to Thrust Line	-14 to + 4 to Thrust Line	
10 Knots	12 Knots	17.1 - 25.6 Knots
59 Knots	59 Knots	
8 sec (10 Knots)		

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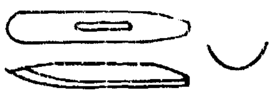
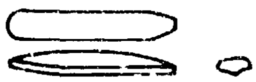
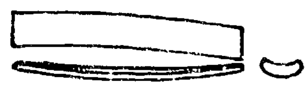
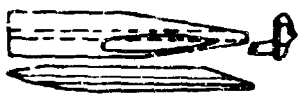
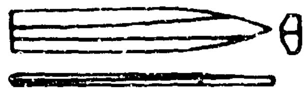
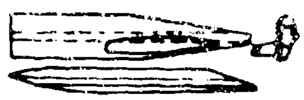
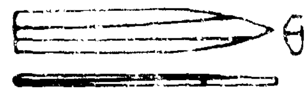
GRUMMAN JRF-5	GRUMMAN JRF-5(OA-9)	XF2Y-1
Ref. 33	Ref. 34	
		
1	1	2
Buoyant	Buoyant	Buoyant
No	No	Yes
Oleo (B25 MG Revised)	Rigid with Rigger Strut	Fwd Linkage, Aft Oleo
8500 lb	8750 - 9140 lb	18,000 - 20,000 lb
191 lb, 172 lb*	223 lb	856 lb, 468 lb*
401 lb*	323 lb	1362 lb, 2750 lb*
464 lb/sq ft	458 lb/sq ft	343 lb/sq ft
	3.5 g Landing Load, Design Maximum*	
24,400 lb*	12,800 - 17,000 lb	
2.87 g	2.9 g	
226,000 in. - lb	236,000 - 137,000 in. - lb	
3.4	3.7	Approximately 10.5
18.3 sq ft	19.9 sq ft	Approximately 58.6 sq ft
12.3 cu ft*	15 cu ft*	24.4 cu ft*
29.7 cu ft*	27 cu ft	50.4 cu ft
2 ft - 4 in. x 8 ft - 8 in.*	2 ft - 4 in. x 9 ft - 4 in.	1 ft - 8 in. x 17 ft - 6 in.*
+3 Fixed	+3 Fixed	
24 Knots	24 29 Knots	12 Knots
60 Knots	60 Knots	
	12 sec	

SKATE 7 (NACA Test Tank) Ref. 35	PSM (M-270)	Proposed Minelayer (Tank Test CVAC) Ref. 36
		
2 Buoyant Yes 1 Fixed Faired Strut, Each Ski	2 and Hydrofoil Buoyant No 2 Rigid Struts, Each Ski	1 Buoyant Yes
33,000 lb 1000 lb, 620 lb* 1620 lb* 660 lb/sq ft	60,000 lb 2413 lb 3245 lb 499 lb/sq ft skis + hydrofoil, 686 lb/sq ft skis	196,000 lb 4440 lb, 6360 lb* 9390 lb 653 lb/sq ft
6 g* 198,000 lb* Total 6 g	3 g 180,000 lb Total 3 g	8 g* 1,570,000 lb* 8 g*
5.42 49.8 sq ft 29 cu ft* 77.2 cu ft* 2 ft - 1½ in. x 13 ft - 0 in.	7.25 Each Ski, 0.486 Foil* 87.5 sq ft Both Skis, 32.8 sq ft Hydrofoil 33.8 cu ft Both Skis, 13.2 cu ft Hydrofoil* 78.8 cu ft* 2 ft - 6 in. x 20 ft each ski, 4 ft - 1⅞ in. x 4 ft - 0 in. each foil	3.9 300 sq ft 450 cu ft* 450 cu ft* 10 ft - 10 in. x 34 ft - 0 in.
2.3 at Hump +2° to Water Line 42 Knots 94 Knots 21 sec	3.4 at Unporting 8 at High Speed 4° to Water Line 35 Knots 80 Knots	[illegible] 34.2 - 38.5 Knots 150 Knots

SKATE 7 (NACA Test Tank)	P5M (K-270)	Proposed Minelayer (Tank Test CVAC)
Ref. 35		Ref. 36
		
2	2 and Hydrofoil	1
Buoyant	Buoyant	Buoyant
Yes	No	Yes
1 Fixed Faired Strut, Each Ski	2 Rigid Struts, Each Ski	
33,000 lb	60,000 lb	196,000 lb
1000 lb, 620 lb *	2415 lb	4440 lb, 6360 lb *
1620 lb *	3245 lb	9390 lb
660 lb/sq ft	499 lb/sq ft skis + hydrofoil, 686 lb/sq ft skis	653 lb/sq ft
6 g*	3 g	8 g*
198,000 lb* Total	180,000 lb Total	1,570,000 lb*
6 g	3 g	8 g*
5.42	7.25 Each Ski, 0.486 Foil*	3.9
49.8 sq ft	87.5 sq ft Both Skis, 32.8 sq ft Hydrofoil	300 sq ft
29 cu ft*	33.8 cu ft Both Skis, 13.2 cu ft Hydrofoil*	450 cu ft*
77.2 cu ft*	78.9 cu ft*	450 cu ft*
2 ft - 1½ in. x 13 ft - 0 in.	2 ft - 6 in. x 20 ft each ski, 4 ft - 1½ in. x 4 ft - 0 in. each foil	10 ft - 10 in. x 36 ft - 0 in.
2.3 at Hump	3.4 at Unporting 8 at High Speed	
+ 2° to Water Line	+ 4° to Water Line	0 to -8
42 Knots	35 Knots	34.2 38.5 Knots
94 Knots	80 Knots	150 Knots
21 sec		

APPENDIX B

STRUCTURAL CONSIDERATIONS

AND

WEIGHT DETERMINATIONS

STRUCTURAL CONSIDERATIONS AND WEIGHT DETERMINATIONS

A. SKI INSTALLATION

The prime advantage of the hydroski-equipped airplanes is their ability to take off and land on various surfaces. They will be capable of landing and taking off from ice, snow, or water and landing in any relatively unobstructed area.

The airplane will be non-buoyant (in the sense that take-off will not be from a buoyant static condition in the water), which necessarily dictates that a minimum planing speed be maintained while on the water. The risk of engine failure while water taxiing does not seem to warrant the weight penalty involved in making a dense airplane of this type into a buoyant configuration. After the landing on water, it is then necessary to taxi to the beach, a prepared ramp, or a floating carrier. Even though the non-buoyant configuration will not take off from a floating position in the water, it is designed to remain afloat in case of a water stall.

The required size of the ramp is a function of minimum water planing speed, thrust to weight ratio, and coefficient of friction. For example, the design selected for comparison has a thrust/weight ratio of 0.50 and a minimum planing speed of 30 knots. If a simple wooden ramp wet-down with water is used, a length of only 120 feet is required to attain the minimum planing speed and transition onto the water. When transitioning from the water at the minimum planing speed, the airplane could be brought to a stop in approximately 150 feet.

Wet sod, mud, or other low friction surfaces may also be used for landing and taking off. Landings on hard surfaces will necessarily be limited to emergencies to preclude excessive ski wear except where some arresting gear device is used to shorten the run out.

The tri-ski configuration shown in Fig. 12 was evolved by considering the importance of having the longest possible bomb bay door and the necessity of providing for lateral stability at low planing speeds. The size of the skis has been selected to maintain a minimum planing speed of 30 knots.

The forward ski (Fig. 29) is retracted into the fuselage aft of Hull Station 193 and extends from longeron to longeron at its widest section. When extended, the forward ski is supported by a 4-bar linkage.

The aft shock strut incorporates a cylinder for adjusting the trim of the ski relative to the airplane by the pilot. In both the retracted and extended positions, the aft strut is secured by a lock on the drag strut. The forward ski is fitted with hinged water flaps that are pilot controlled to vary the effective ski area. The water flaps are extended in order to maintain a low planing speed and retracted for landing and high speed planing.

Smaller skis (Fig. 30) are attached to each wing tip, and when retracted, they form the wing's lower contour. A trim cylinder is included in the supporting linkage so that ski trim may be pilot controlled. The tip skis are secured in the down position by a lock on the main strut, and secured in the up position by a sequence operated lock on the wing structure.

From this preliminary investigation, it was determined that the use of hydroskis will save a total of 60 of the 90 cubic feet of fuselage volume required in the conventional wheel landing gear. The total weight saving of the skis over the landing gear is considered to be negligible.

All three skis have pointed trailing edges which are intended to reduce landing impact loadings and vibration problems at high speed planing. Should maneuverability for ground handling be desired on a hard surface where ski wear would be too great, small handling wheels may be installed integral with the skis. For the tip skis, this would require a fairing in the wing to house the wheel.

B. DETERMINING THE SKI SIZE

In establishing the ski size for the attack airplane, which has a gross weight of approximately 30,000 lb, it was assumed that the minimum planing speed should be approximately 50 fps (30 knots). The problem then boiled down to a determination of the area, aspect ratio, and trim that would support the required loads. One of the major problems was the determination of the number of skis and their arrangement in a manner that would be compatible with the selected airframe.

Initial studies revolved around a single ski configuration with small outriggers on each wing. It became increasingly obvious that this system was impractical because the required ski

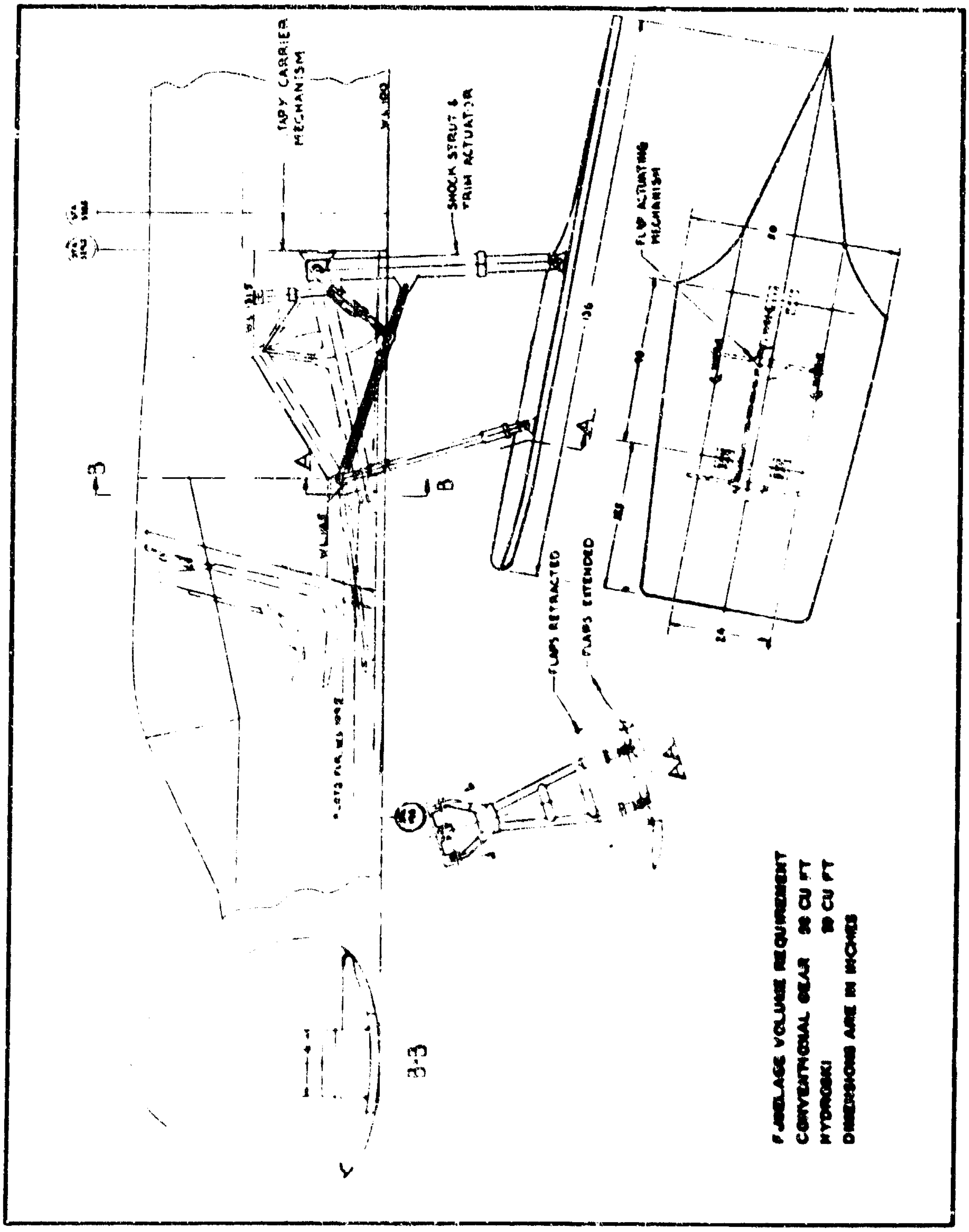


Fig. 29. Main Ski

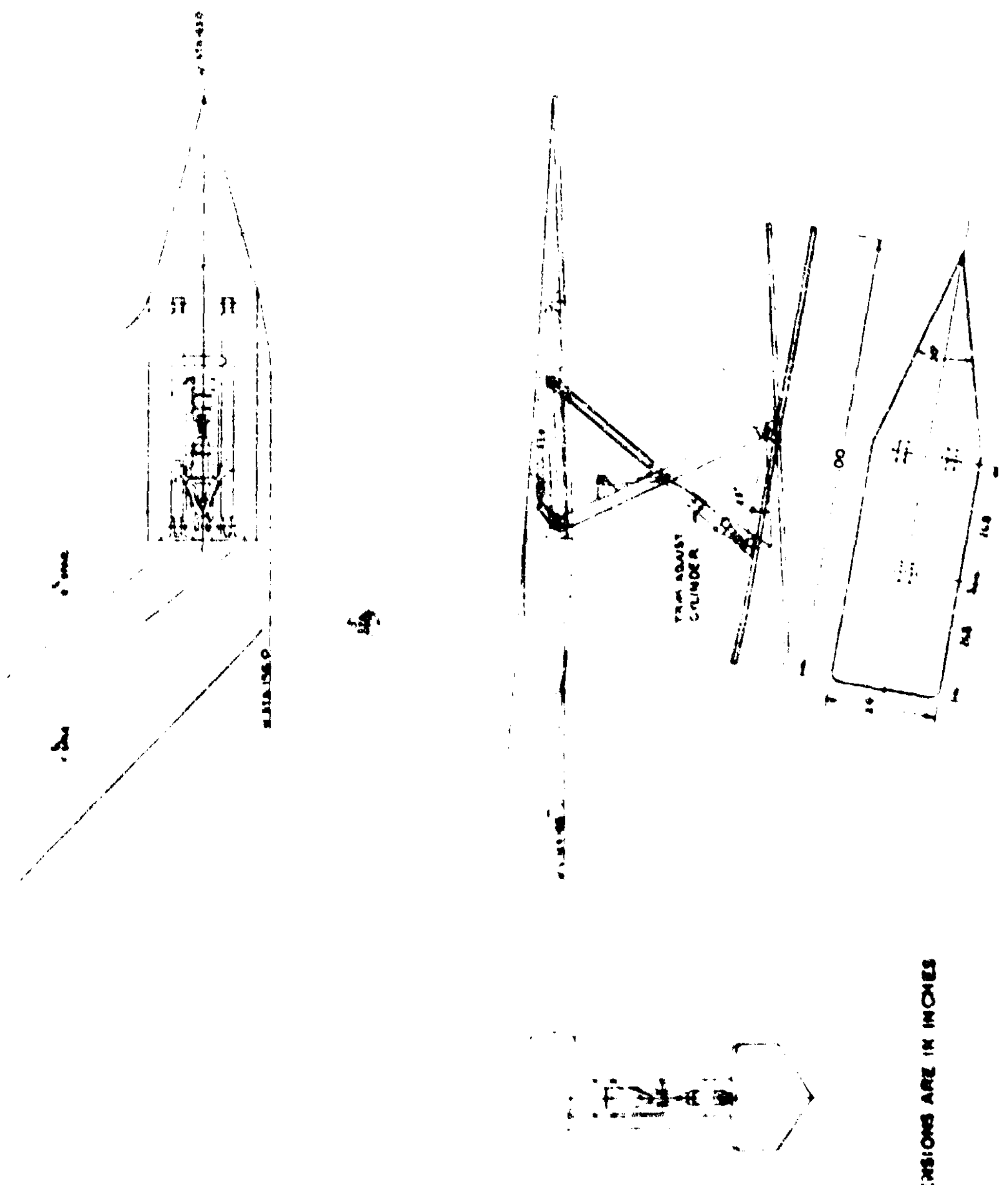


Fig. 30. Tip Ski

area could not be fitted into the available fuselage volume and/or bottom area. This same factor precluded the use of twin skis unless they could be retracted into the wing bottom surface. Retraction into the wing was not seriously considered because of the wing structure and the difficulties which might arise due to space problems. Thus, it was decided that a 3-point suspension be used with $\frac{1}{2}$ the weight being carried by the main ski and $\frac{1}{4}$ on each wing tip ski.

In determining the lift it was estimated that a trim angle of 14 degrees would be satisfactory and would not provide drag forces that would exceed the available thrust (Ref. 13). The width of the main ski was determined by the main fore and aft longerons while the length was established by the available space forward of the bomb bay. Based on experience with the F2Y, NACA and AAE, as well as Martin, a pointed stern was included to relieve impact loads. The resulting main ski area totaled approximately 33 square feet. The outer edges were designed to be retractable so that the maximum width would be reduced during the high speed planing and/or landing operation. Other pertinent factors for this main ski are listed below:

Symbols.-

S = area (sq ft)

b = width (ft)

b_{ave} = average width (ft)

β = deadrise angle (deg)

β_e = effective deadrise angle (deg)

Δ - hydrodynamic lift (lb)

L = length (ft)

τ - ski trim angle (deg)

R = hydrodynamic resistance (lb)

T = thrust (lb)

S = 33 sq ft

b_{ave} = 4 ft

β_e = 0° (estimated)

τ = 14°

$$\frac{L}{b} = \frac{S}{b^2} = \frac{33}{16} = 2.06$$

From Ref. 13

$\frac{\Delta}{S}$ was determined to be approximately 500 lb/sq ft

Δ = 33 x 500 = 16,500 lb

The tip ski was determined in a manner similar to that used for the main ski. Care was exercised to assure a minimum disturbance to the basic structure. Pertinent factors for these skis are:

$$S = 13 \text{ sq ft} \qquad \tau = 14°$$

$$b = 2.00 \qquad \beta = 0$$

$$\frac{L}{b} = \frac{S}{b^2} = \frac{13}{4} = 3.25$$

From Ref. 13

$\frac{\Delta}{S}$ was determined to be approximately 450 lb/sq ft

Δ = 13 x 450 = 5,850 lb for a total of 11,700 lb/sq ft

The inverse lift/drag ratio at these speeds is given below as determined by methods outlined in Ref. 13.

$$\text{Main ski } \frac{R}{\Delta} = 0.275$$

$$\text{Tip ski } \frac{R}{\Delta} = 0.278$$

Since $\frac{T}{\Delta}$ exceeds 0.300 it can readily be seen that there is sufficient thrust to maintain these speeds. Typical take-off resistance and performance is shown in Fig. 31.

To establish planing equilibrium, it was necessary to consider ski positions as well as forces of thrust, lift, drag, and weight.

C. WEIGHT COMPARISON

The statistical comparison of skis and wheeled landing gears in Appendix A indicates a lighter weight for ski installations. Information available on skis is very limited and is not representative of a production type installation. Also, the statistical analysis dealt only with the landing device with its supporting

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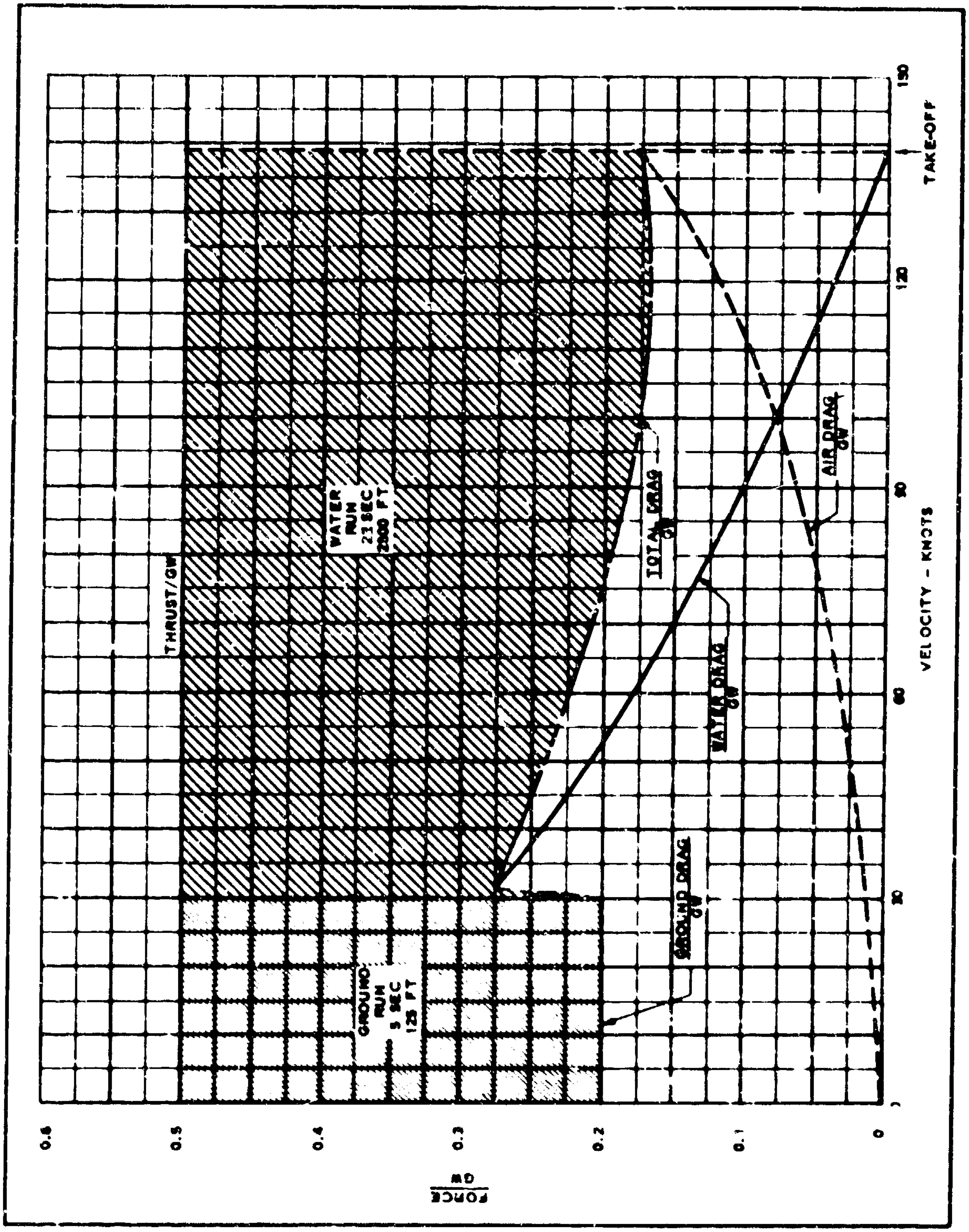

Fig. 31. Attack Aircraft Take-Off Performance

struts and, as such, can only be used to indicate a trend. The type, size, and location of landing devices appreciably affect the aircraft configuration and structural design. A direct comparison can only be made by an analysis of specific designs.

For this comparison a land-based airplane configuration has been selected that has a tandem landing gear housed in the fuselage with auxiliary wing-tip gear; the water-based version has a single main ski housed in the fuselage and twin skis located on the wing tips.

Undoubtedly there will continue to be developments in the aircraft structural field in the period covered by these studies. Improvements may be expected in construction methods and in the quality of the materials used. Honeycomb construction for control surfaces and secondary structures will be used more extensively. The development of very high heat treated, high strength 4340 steel will have a minor effect on the over-all design. New aluminum alloys are being developed of which the XA785 series is presently showing an 8 per cent increase in tensile strength over the 75S series. Fatigue strength and other physical properties are about the same as 75S and it will have approximately the same limitations in its use. Titanium alloys in development that retain their strength at elevated temperature are now approaching the strength-weight ratio of the aluminum alloys. High production and a subsequent reduction in cost will encourage more extensive use of this alloy.

The foregoing developments in the field of aircraft structural design will tend to lower the structural weight. Unfortunately, there are other considerations such as corrosion, fatigue, and temperature problems that will have an opposite effect and may nullify any expected improvement. It is assumed, therefore, that the estimating procedures based on current performance will satisfactorily predict structural weights for the period covered by this study.

The summary weight comparison of the ski-equipped and wheel-equipped attack airplanes was given in Table 1.

1. Method of Analysis

Methods used for the weight analysis of aircraft vary with the purpose for which the analysis is prepared and the time available for the evaluation of specific configurations. Generalized formulas for the estimation of structural components are usually developed from statistical information with a purely emperical or a semi-theoretical base. In general, each aircraft manufacturer and military struts and, as such, can only be used to indicate a trend. The type, size, and location of landing devices appreciably affect the aircraft configuration and structural design. A direct comparison can only be made by an analysis of specific designs.

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1. Method of Analysis

Methods used for the weight analysis of aircraft vary with the purpose for which the analysis is prepared and the time available for the evaluation of specific configurations. Generalized formulas for the estimation of structural components are usually developed from statistical information with a purely empirical or a semi-theoretical base. In general, each aircraft manufacturer and military procuring agency has developed or adopted its own methods and formulas for weight analysis. Many of these methods have been presented as papers to technical societies and others are available as the result of contractural efforts of research organizations such as Rand, Inc., and the Willow Run Research Center. A number of these methods were available and investigated for use.

For this analysis a method was needed that would provide generalized formulas for major structural components and provide a reasonably accurate total component weight in a short period of time. It was also necessary that these formulas contain the parameters affecting weight in their proper relationship to the total so that the formulas could be used in the optimization studies of the individual components.

Of the formulas investigated, those used in this analysis that have been based on methods used at the Martin Company and those contained in Ref. 28 and applied in Ref. 29 were found to have the most consistent accuracy. Methods using a more detailed theoretical analysis as exemplified by the multiple station analysis of Ref. 30, require considerably more time to apply and are only valuable as a more refined check when the situation warrants.

In the following analysis, fairly detailed stress checks were made on the major structural components. This procedure was followed because of the rather unconventional fuselage configuration dictated by the "area rule" and because of the effects of the landing devices and their locations on the fuselage and wing. These structural analyses checked very closely with the results obtained by estimating formulas.

Symbols.-

DGW = design gross weight (lb)

W_W = basic wing weight (lb)

W_{HT} = total horizontal tail weight (lb)

W_{VT} = total vertical tail weight (lb)

W_F = basic fuselage weight (lb)

ω_S = ski unit weight (lb/sq ft)

ω_{HT} = horizontal tail unit weight (lb/sq ft)

ω_{VT} = vertical tail unit weight (lb/sq ft)

ULF = ultimate load factor (g)

S = area (sq ft)

b = span (ft)

AR = aspect ratio

$\Lambda_{c/4}$ = sweepback angle at the quarter chord (deg)

C_R = root chord (ft)

C_T = tip chord (ft)

t = maximum airfoil thickness (ft)

t_R = maximum root chord thickness (ft)

t_T = maximum tip chord thickness (ft)

t_e = effective airfoil thickness (ft) $= \frac{2t_R + t_T}{3}$

λ = taper ratio C_T/C_R

$b_{c/4}$ = span of quarter chord (ft)

UTL = ultimate tail load (lb)

H = height (ft)

L = length (ft)

W = width (ft)

P = total load (lb)

K = (a constant)

3. Basic Weight Estimating Formulas:

Wing weight.- The wing weight formula used is basically the Martin Empirical formula rearranged to a convenient form for use in estimating and optimization.

Basic wing weight $W_w = K_1 \left[\dfrac{b}{\cos \Lambda_{c/4}} \right]^{.63} \left[\dfrac{ULF \times DGW \times S}{t_e} \right]^{.63}$

or

$$W_w = K_2 \left[\frac{AR\ (1 + \lambda)}{\cos \Lambda_{c/4}\ (2 \frac{t_R}{C_R} + \frac{\lambda t_T}{C_T})} \right]^{.63} (ULF \times DGW \times S)^{.63}$$

The term $\left(\dfrac{W_w}{(ULF \times DGW \times S)}\right)^{.63}$ from the above equation can be conveniently used as a weight factor in configuration optimization studies in which this factor is plotted against varying aspect ratio, sweep-back, taper ratio, and airfoil thickness.

Empennage

Horizontal Tail

$$\omega_{HT} = K_3 \left[\frac{UTL}{S} \times \frac{b_{c/4}}{t_e} \right]^{\frac{1}{2}} + 1.375$$

$$W_{HT} = \omega_{HT} \times S$$

Vertical Tail

$$\omega_{VT} = K_4 \left[\frac{UTL}{S} \times \frac{b_{c/4}}{t_c} \right]^{\frac{1}{2}} + 1.5$$

$$W_{VT} = \omega_{VT} \times S$$

Fuselage

$$W_F = K_5 \times L\ (W + H)$$

Skis

$$\omega_S = K_6 \left(ULF \times \frac{P}{S} \times \frac{L}{W}\right)^{\frac{1}{2}}$$

4. Weight Derivation - Water-Based Airplane

Wing Group

ULF	=	13	b	=	33 ft
S	=	320 sq ft	$\Lambda_{c/4}$	=	45°
AR	=	3.4	t_T	=	0.833 ft
C_R	=	11.62 ft	λ	=	0.667
C_T	=	7.75 ft	$\lambda(t_R)$	=	0.833 ft
DGW	=	22,300 lb	K_2	=	0.0033 (statistically determined)

$$W_w = 0.90^{*} \times K_2 \left[\frac{AR \times (1+\lambda)}{(\cos \Lambda_{c/4})\left(2\frac{t_R}{C_R} + \lambda \frac{t_T}{C_T}\right)} \right]^{.63} (ULF \times DGW \times S)^{.63}$$

$$W_w = 0.90 \times 0.0033 \left[\frac{3.4 \times (1 + 0.667)}{0.707\,(2 \times 0.071 + 0.667 \times 0.1075)} \right]^{.63}$$

$$(13 \times 22,300 \times 320)^{.63}$$

$$W_w = 3,000 \text{ lb}$$

*NOTE: Factor of 0.90 [illegible] efficient type of wing configuration.

Wing Weight	3,000 lb
Wing Special Features	
Leading Edge Flap (25 x 2 lb/sq ft)	50
Dive Brake Provision (36 x 4 lb/sq ft)	144
External Stores Provision	60
Tip Ski Provision	60
Effect of Tip Ski Loads on Structure	35
Surface Control Provision	22
Anti-Icing Provision (320 x 0.06 lb/sq ft)	19
Fuel Provisions (539 x 0.09 lb/gal)	48
TOTAL	3,488 lb

Tail Group

Horizontal Tail

$S = 79$ sq ft

$C_R = 8.92$ ft

$C_T = 1.35$ ft

$b = 15.4$ ft

$b_{c/4} = 21.8$ ft

$\frac{t}{c} = 6$ per cent

$t_R = 0.535$ ft

$t_T = 0.080$ ft

$t_e = 0.383$ ft

$\Lambda_{c/4} = 45°$

$UTL = 46,000 \times 1.5 = 69,000$ lb

$K_5 = 0.0306$ (statistically determined)

$$W_{HT} = K_5 \left[\frac{UTL}{S} \times \frac{b_{c/4}}{t_e} \right]^{\frac{1}{2}} + 1.375 = 0.0306 \left[\frac{69,000}{79} \times \frac{21.8}{0.383} \right]^{\frac{1}{2}} + 1.375$$

$= $ [illegible].15 lb/sq ft

$W_{HT} = \omega_{HT} \times S$

$W_{HT} = 8.15 \text{ lb/sq ft} \times 79 \text{ sq ft} = 644 \text{ lb}$

Vertical Tail

$S = 37$ sq ft	$t_R = 0.48$ ft
$C_R = 8.0$ ft	$t_T = 0.12$ ft
$C_T = 2.0$ ft	$t_e = 0.36$ ft
$b = 7.42$ ft	$\frac{t}{c} = 6$ per cent
$b_{c/4} = 11.5$ ft	$K_4 = 0.0528$ (statistically determined)
$\Lambda_{c/4} = 50°$	UTL = 16,900 x 1.5 = 25,350 lb

$$\omega_{VT} = K_4 \left[\frac{UTL}{S} \times \frac{b_{c/4}}{t_e} \right]^{\frac{1}{2}} + 1.5 = 0.0528 \left[\frac{25,350}{37} \times \frac{11.5}{0.36} \right]^{\frac{1}{2}} + 1.5$$

$$= 9.3 \text{ lb/sq ft}$$

$W_{VT} = \omega_{VT} \times S$

$W_{VT} = 9.3 \text{ lb/sq ft} \times 37 \text{ sq ft} = 344 \text{ lb}$

Horizontal Tail	644 lb
Vertical Tail	344
TOTAL	988 lb

Fuselage

L = 32.0 ft	H = 4.67 ft
W = 5.0 ft	K_5 = 6.72 (statistically determined)

Basic Fuselage Weight

$$W_F = K_5 \times L (W + H^{\frac{1}{2}})$$

$$= 6.72 \times 52.0 (5.0 + 4.67^{\frac{1}{2}}) = 2,506 \text{ lb}$$

Dive Brakes (15.3 x 10.0 lb/sq ft)	153
Rotary Bomb Door	265
Guns and Ammunition Provision	50
Electronics Provision (0.06 x 697 lb)	42
Cabin Pressurization Provision	50
Ski Provision	125
Engine Installations Provision	100
Fuel Tank Provision (796 x 0.10 lb/gal)	80
Surface Controls Provision	30
Hydraulic and Electrical Systems Provision	35
TOTAL	3,436 lb

Landing Ski Group

Main Landing Ski

S (Main) = 20 sq ft   P = 14,000 lb

S (Hinged) = 13 sq ft   ULF = 3.5 g

L = 11.6 ft   Landing Gross Wt = Take-off Gross Wt Less 50% Fuel and Bombs

W (Over-all) = 4.33 ft

W (Basic Ski) = 2.0 ft K_6 = 0.112 (statistically determined)

$\frac{L}{W}$ (Basic Ski) = 5.8

$$\omega_S = K_6 \left(ULF \times \frac{P}{S} \times \frac{L}{W}\right)^{\frac{1}{2}}$$

$$= 0.112 \left(3.5 \times \frac{14,000}{33} \times 5.8\right)^{\frac{1}{2}}$$

$$= 10.4 \text{ lb/sq ft}$$

Basic Ski Weight = $\omega_S \times S$ = 10.4 x 20 = 208 lb

Hinged Ski Wt = $\omega_S \times S$ = 7.0 x 13 = 91 lb

Main Ski		299 lb

Forward Strut (Rigid)

L = 3.9 ft

Max Resultant Reaction = 21,700 lb

Strut Weight = L x 18 lb/ft = 70 lb

Aft Strut (Oleo)

L = 50 in.

Max Resultant Reaction = 50,400 lb

Strut Weight = L x 5.0 lb/in. = 250 lb

Struts		320 lb
Operating Mechanism (10% Wt Retr)	= 62 lb	
Ski Folding Mechanism	= 12 lb	
Mechanism		74 lb
Total Main Ski		693 lb

Wing Tip Landing Skis

Tip Skis

S = 13.3 sq ft (each) ULF = 3.5 g

L = 6.34 ft K_6 = 0.112 (statistically determined)

$W = 2.1$ ft

$P = 7{,}000$ lb

$$\omega_S = K_6 \left(ULF \times \frac{P}{S} \times \frac{L}{W}\right)^{\frac{1}{2}}$$

$$= 0.112 \left(3.5 \times \frac{7000}{13.3} \times \frac{6.24}{2.1}\right)^{\frac{1}{2}}$$

$= 8.3$ lb/sq ft

Ski Weight $= \omega_S \times S = 8.3 \times 13.3 \times 2 = 220$ lb

Strut

$L = 2$ ft

Max Resultant Reaction = 21,000 lb

Strut Weight = L x 27.6 lb/ft x 2 =	110 lb
Operating Mechanism (10% Wt Retr) =	33 lb
Total Tip Skis	363 lb

Summary:

Main Skis	693 lb	
Tip Skis	363 lb	
Total Skis		1,056 lb

Surface Controls

Cockpit Controls	40	
Automatic Pilot (E-9)	100	
System Controls	533	
Total		673 lb

Engine Section Group

Engine Mount	37	
Engine Tracks	11	
Fire Walls and Shrouding	110	
Engine Access Doors	50	
Tension Bolt Splice for Removal	60	
Provision for Anti-Icing	5	
TOTAL		273

Propulsion Group

Engine with Afterburner (1) GE XJ79 XX-24A		3,120	
Engine Nose Fairing		15	
Air Intake Duct 40 in. x 1.0 lb/in. + 5 lb		45	
Afterburner Blanket		52	
Generator Cooling Ducts		7	
Zone II Cooling Ducts		26	
Fuel Tanks (non self-sealing, rip-ram type)			
Fuse #1(2) 138 gal	66		
Fuse #2(2) 68 gal	41		
Fuse #3(1) 218 gal	37		
Fuse #4(1) 166 gal	35		
		179	
Fuel Transfer Pumps		85	
Fuel Plumbing		192	
Single Point Fueling System		45	
Air Refueling System (excluding probe)		10	
Water Injection System (30 gal)		50	
Engine Controls		15	
Starter-Pneumatic (ext power source)		30	
Starter Installation		3	
TOTAL			3,354 lb

Fixed Equipment

Instrument Group	Total	114 lb
Hydraulic Group	Total	445 lb
Electrical System	Total	650 lb

Electronics Group

AN/ARC-34 (Radio Set)	69 lb	
AN/ARN-21 (TAC Omni-range Nav.)	66	
AN/APW-11A (Mark Beacon)	51	
AN/APS-54 (Tail Warning)	19	
AN/APX-19 (IFF)	57	
AN/APX-27 (IFF)	41	
AN/APN-79 (GPI)	173	
Break Away Computer	12	
Fire Control	316	
Shelves Supports etc.	21	
TOTAL		825 lb

Armament Group

Pilots Protection	300 lb	
Bomb and Rocket Release System	15	
Bomb Door Mechanism	120	
Gun Mounts, Rings, and Supports	50	
Ammunition Chutes	23	
Ammunition Boxes	72	
Blast Tunnels	15	
TOTAL		595 lb

Furnishings	355 lb
Air Conditioning	145 lb
Anti-Icing Group	176 lb
Total Fixed Equipment	3,305 lb

TOTAL WEIGHT EMPTY - WATER-BASED ATTACK AIRPLANE 17,073 lb

5. Weight Derivation - Land-Based Attack Airplane

Wing Group

Water-Based Total Wing Weight	3,488 lb	
Adjustment made for local gear provisions	-26	
Structural adjustment to basic wing for removal of wing tip skis	-85	
Total Wing Group		3,377 lb

Tail Group

(same as water-based version) 988 lb

Fuselage Group

$L = 52.0$ ft
$W = 5.0$ ft
$H = 4.67$ ft
$W_F = K_5 \times L\,(W + H^{\frac{1}{2}})$

$= 7.1 \times 52.0\,(5.0 + 4.67^{\frac{1}{2}}) =$ 2,643 lb

Note: Difference in weight between water- and land-based basic fuselage weights calculated from stress evaluation of respective designs.

Dive Brakes (15.3 sq ft x 10.0 lb/sq ft)	153 lb
Rotary Bomb Door	265
Landing Drag Chute Provision	50
Guns and Ammunition Provision	50
Electronics Provision	42
Cabin Pressurization Provision	50
Landing Gear Provision	150
Engine Installation Provision	100
Fuel Tank Provision	80
Surface Control Provision	30
Hyd. and Elec. System Provision	35

Total Fuselage Weight 3,648 lb

Landing Gear Group

Main Landing Gear (Aft)

Landing weight = normal gross weight less 50% fuel and bombs = 22,454 lb
ULF = 4.0
L = 45.5 in. (℄ axle to top of oleo extended)

$$\text{Landing Kinetic Energy} = \frac{22{,}545 \times (200\ \text{ft/sec})^2}{2 \times (32.2\ \text{ft/sec}^2)}$$

= 14,003,000 ft-lb
Max Resultant Load = 95,050 lb
Brake Kinetic Energy (0.8 x landing k.e.) 11,202,000 ft-lb

Structure		
45.5 in. x 7.25 lb/in.	330 lb	
Wheels (36 by 11) (2 x 59.5)	119	
Brakes (11,202,000 x 0.000014)	157	
Tires (36 by 11) 14 ply	140	
Tubes and air	25	
Operation Mechanism 0.06 x 771	46	
TOTAL		817 lb

Nose Landing Gear

Length Axle to ℄ Trunnion 48 in.		
Max Resultant Reaction 14,420 lb		
Structure		
48 in. x 1.75 lb/in.	84 lb	
Wheels (20 by 4.4) (2 x 13)	26	
Tires (20 by 4.4) 10 ply	24	
Tubes and air	4	
Steering Mechanism	20	
Operating Mechanism 0.10 x 158	16	
TOTAL		174 lb

Wing Tip Landing Gear

Length Axle to ℄ Trunnion 44 in.		
Max Reaction 6,000 lb.		
Structural Weight		
2 x 44 in. x 1.0 lb/in.	88 lb	
Solid Rubber Wheel	12	
Operational Mechanism 0.10 x 100	10	
TOTAL		110 lb

Drag Chute Installation

Parachute (18 ft dia)	21 lb	
Release Unit	16	
TOTAL		37 lb
TOTAL		1,138 lb
TOTAL WEIGHT EMPTY - LAND-BASED ATTACK AIRPLANE		17,256 lb

6. Structural Weight Adjustments for Carrier Basing

Certain weight penalties are associated with the carrier basing of aircraft. These penalties stem from three structural considerations:

1) Arresting loads and the mechanism required for arrested landings;

2) Catapulting loads and the provisions for this type of take-off; and

3) The higher landing loads associated with higher sinking speeds and movement of the carrier.

Arresting provisions usually consist of a hook, snubber, retracting and release mechanism, and the structure required to distribute the loads in the airplane (usually the aft fuselage). Arresting loads of 3 to 4 g, depending on run-out length and engaging speed, are developed. Considerable local structural beef-up is usually required. The weight penalty associated with arrested landing is on the order of 0.6 to 0.9 per cent of the gross weight of the aircraft. This penalty would apply to either wheeled or ski-type aircraft.

Catapulting provisions usually consist of a pair of fittings or hooks to take the forward and the down loads of 4 g and 2 g respectively, and a third fitting that holds the aircraft in starting position until a predetermined catapulting load is attained. These fittings can usually be located close to primary structure and result in a negligible weight penalty when expressed as a percentage of gross weight. This same penalty would apply to both wheeled and ski-equipped aircraft. A problem unique with the catapulting of the ski-equipped aircraft is the high frictional loads because of the ski on the deck with the 2 g applied down load. A modification to the carrier deck in the catapulting area or some form of lubrication may be required to alleviate this condition.

Landing gear design criteria for carrier-based operation are based on a sinking speed of 17 feet per second as compared to 10 feet per second for normal land-based landings. The stress imposed on the carrier gear is three times as great as the stress on the land-based gear.

These higher loads cause a weight penalty of from 0.8 to 1.4 per cent of the gross weight of the airplane. Recent developments in carrier design have resulted in the canted deck concept, as installed on the USS Antietam. This concept of a power-on wire engagement results in sinking speeds that are significantly lower and may conceivably approach those of land-based aircraft. Loads developed by ski-equipped aircraft landing on water will be apprecia[bly] lower than loads developed by land-based aircraft. However, the ai[r]craft selected for the comparison was considered to be panto-based so that loads comparable to land-based aircraft would be developed and shock absorbing devices would have to be of the same capacity. With this assumption, the penalty associated with carrier basing sho[uld] be approximately the same on ski-equipped as on land-based aircraft. Studies have indicated that, as in catapulting, higher airplane dra[g] loads may be developed in the carrier landing of a ski-equipped air-plane due to additional friction between ski and deck. The solutio[n] may lie in some form of lubrication on the ski or carrier deck in t[he] landing area.

From the foregoing, it can be concluded that structural problems associated with carrier landing of the ski-equipped aircraft in thi[s] comparison are similar to those of normal land-based aircraft.